

How to Plan a Manufacturing Cell

This Planning Guide explains step by step how to plan a manufacturing cell. It discusses the information and analyses required at each step and the outputs achieved. Several types of cells are discussed. Special issues related to automation are also discussed. A comprehensive checklist is provided covering all major aspects of cell planning and operation, including physical arrangement, operating procedures, organization and training.

KEY TOPICS	page
Types of Manufacturing Cells	3
Six-Step Planning Process for Simple Cells	4
Complex Cells and Issues	18
Checklist for Cell Planning & Design	22

BACKGROUND

Definition of a Manufacturing Cell

A manufacturing cell consists of two or more operations, work stations, or machines dedicated to processing one or a limited number of parts or products. A cell has a defined working area and is scheduled, managed, and measured as a single unit of production facilities. Typically, a cell is relatively small, and may be virtually self-managed. Usually, the outputs of a cell are more-or-less complete parts or assemblies, ready for use by a downstream operation or cell, or for shipment to a customer.

Three aspects— physical, procedural, and personal – must be addressed when planning a manufacturing cell. Cells consist of *physical facilities* such as layout, material handling, machinery, and utilities. Cells also require *operating procedures* for quality, engineering, materials management, maintenance, and accounting. And because cells employ *personnel* in various jobs and capacities, they also require policies, organization, leadership, and training.

A cell is essentially a production line (or layout by product) for a group or family of similar items. It is an alternative to layout and organization by process, in which materials typically move through successive departments of similar processes or operations. This layout by process generally leads to higher inventories as parts wait between departmental operations, especially if larger batches or lots are produced. There is more material handling is required to move between departments, and overall processing time is longer. Exposure to quality problems is greater, since more time may pass and more non-conforming parts may be produced before the downstream department notices a problem.

Benefits of Cells

The principal physical change made with a manufacturing cell is to reduce the distance between operations. In turn, this reduces material handling, cycle times, inventory, quality problems, and space requirements. Plants installing cells consistently report the following benefits when compared to process-oriented layouts and organizations:

- Reduced materials handling – 67% to 90% reductions in distance traveled are not uncommon, since operations are adjacent within a dedicated area.
- Reduced inventory in process – 50% to 90% reductions are common, since material is not waiting ahead of distant processing operations. Also, within the cell, smaller lots or single-piece flow is used, further reducing the amount of material in process.
- Shorter time in production – from days to hours or minutes, since parts and products can flow quickly between adjacent operations.

In addition to these primary, quantifiable benefits, companies using cells also report:

- Easier production control
- Greater operator productivity
- Quicker action on quality problems
- More effective training
- Better utilization of personnel
- Better handling of engineering changes

These secondary benefits result from the smaller, more-focused, and simplified nature of cells.

Difficulties in Planning & Managing Cells

To obtain the benefits of cells, planners and managers must overcome the following difficulties:

- Worker rejection or lack of acceptance – often due to lack of operator involvement in planning the cell, or to insufficient motivation and explanation by management, especially if the outcome is perceived to be a work force reduction.
- Lack of support or opposition by support staffs in production planning, inventory control and/or cost accounting – usually when creation of the cell causes changes in procedures and practices, or reduces the amount of detail reported from the plant floor.
- Reduced machine utilization – due to dedication of equipment to cells and to families of parts. In some cases, additional, duplicated machinery may be required. In other cases, large and high-speed equipment that may be appropriate in a process-oriented department or job shop must be replaced by slower and usually smaller, lower-capacity machines that are more appropriate to the volumes of a cell.

- Need to train or re train operators, often for a wider range of duties and responsibilities.
- Wage and performance measurement problems, especially when individual and piece-rate incentives are in use. The team-oriented nature of the typical cell and the goals of inventory reduction may work against traditional incentives and measures.

TYPES OF MANUFACTURING CELLS

Cells take different forms based upon the characteristics of the parts (P) and quantities (Q) produced, and the nature of the process sequence or routing (R) employed. The relationship of these characteristics – P, Q, and R – and their influence on manufacturing cells can be seen in Figure 1.

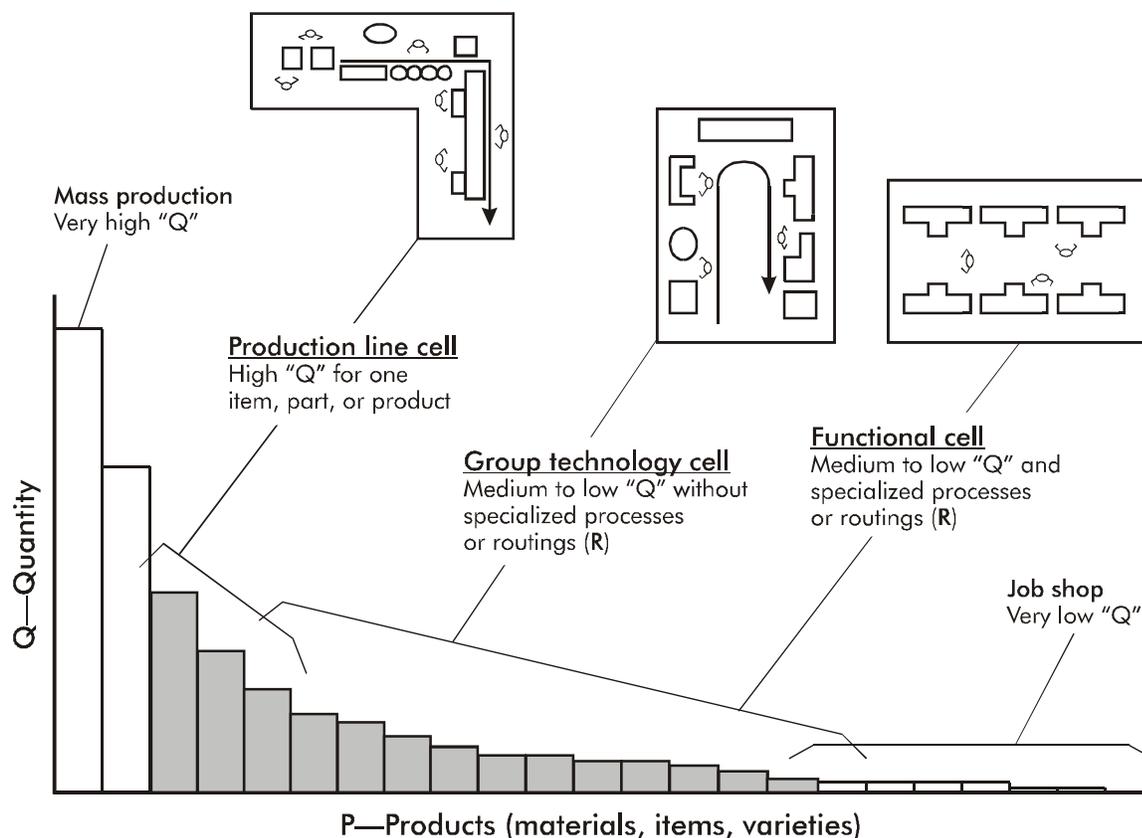


Figure 1. Key Considerations and Types of Manufacturing Cells. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

Production Line, Group of Parts, and Functional Cells

Cells are typically used to serve the broad middle range of a Product-Quantity (P-Q) distribution. Very high quantities of a part or product – typically above 1 million units per year – lend themselves to dedicated mass-production techniques such as high-speed automation, progressive assembly lines, or transfer machines. At the other extreme, very low quantities and intermittent production are insufficient to justify the dedicated resources of a cell. Items at this

end of the P-Q curve are best produced in a general-purpose job shop. In between these quantity extremes, are the many items, parts or products that may be grouped or combined in some way to justify the formation of one or more manufacturing cells.

Within the middle range, a *production line cell* may be dedicated to one or few high-volume items. This type of cell will have many of the attributes of a traditional progressive line, but is usually less mechanized or automated.

Medium and lower production quantities are typically manufactured in *group technology* or *group-of-parts cells*. These are the most common types of cells. They exhibit progressive flow, but the variety of parts and routings works against a production line.

If the processing steps are specialized in some way, requiring special machinery and utilities, or special enclosures of some kind, then a *functional cell* may be appropriate. Functional cells are often used for painting, plating, heat treating, specialized cleaning, and similar batch or environmentally sensitive operations. If the functional cell processes parts for other group-of-parts or production line cells it will introduce extra handling, cycle time and inventory since parts must be transported and held ahead of and behind the functional cell. For this reason, planners should first examine the practicality of decentralizing or duplicating the specialized process(es) into group-of-parts or production line cells.

The steps required to plan a manufacturing cell are the same for all three types of cells – production line, group technology, and functional. However, the emphasis and specific techniques used will vary somewhat based upon the physical nature of the manufacturing processes involved. For example, when planning for machining and fabrication cells the capacity of key machines is critical and may be relatively fixed. The time required to change from one part or item to another is also critical. Allowances for set-up and capacity losses to changeovers are very important. Manpower planning may be of secondary importance, after the number of machines has been determined. In contrast, when planning for progressive assembly, the variability of operation times must be understood, and the work must be balanced among the operators to assure good utilization of labor. In such assembly cells, utilization of equipment may be a secondary issue.

HOW TO PLAN A MANUFACTURING CELL

Most cells can be planned using a simple six-step approach:

1. Orient the Project
2. Classify the Parts
3. Analyze the Process
4. Couple into Cell Plans
5. Select the Best Plan
6. Detail and Implement the Plan

This approach is fully-described in the booklet: *Simplified Systematic Planning of Manufacturing Cells*, by Richard Muther, William E. Fillmore, and Charles P. Rome. See Reference 2. A synopsis of this approach is presented here by permission of the authors.

Step 1. Orient the Project

The cell planner's first step is to organize the project, beginning with a statement of objectives, operational goals, and desired improvements. External conditions imposed by the facility or the surroundings should be noted. The planning or business situation is also reviewed and understood for issues such as urgency and timing, management constraints, or other policy matters. The scope of the project and the form of the final output are agreed upon.

All cell-planning projects begin with a set of open "issues". These are problems, opportunities, or simply questions that will affect the planning of the cell or its subsequent operation. These issues must be resolved and answered during the planning process. Typical issues include: responsibilities for inspection and maintenance, cost accounting methods, scheduling procedures, job design and training; in addition to physical issues related to available space, equipment, and utilities. The planner and the planning team should list their issues at the first opportunity, and rate the relative importance of each to the project.

Orientation also requires an achievable project schedule, showing the necessary tasks and the individuals assigned to each. The essential planning tasks can be established using the six-step procedure outlined above, adapted to the specifics of the project at hand. The final output of Step 1 – Orientation can be summarized on a simple worksheet like that shown in Figure 2.

Step 2. Classify the Parts

Most projects have a candidate list of potential parts that could be made in the cell. These parts typically have the same or similar routings. The planner must still clarify and confirm that these candidate parts do belong in the cell, and identify those that do not. Classifying the parts also simplifies the analysis and design of the cell. The first cut at classification usually involves the physical characteristics of the candidate parts. These include:

- Basic material type
- Quality level, tolerance, or finish
- Size
- Weight or density
- Shape
- Risk of damage

Additional common considerations for classification include:

- Quantity or volume of demand
- Routing or process sequence (and any special or dominant considerations)
- Service or utility requirements (related to the process equipment required)
- Timing – (may be demand-related, e.g. seasonality; schedule-related peaks or valleys; shift-related; or possibly related to processing time if some parts have very long or very short processing times).

ORIENTATION & ISSUES WORKSHEET

Project Name Oven Assembly Cell Project No. 99509
 By Team With DM
 Date 10/8 Sheet 1 of 1

1 Objectives Reduce material handling; accommodate plant ordering procedures; minimize throughput time; attain desired output rate, no more, no less.

2 External Conditions Locate in old Receiving area. Moves of baskets and totes-on-pallets by fork truck.

3 Situation Quick start up required to meet customer demand. Use available equipment.

4 Scope and Form of Output Cell must start deliveries by 11/15.

No	PLANNING ISSUES	I	E	A	Action to Resolve	Resp	Proposed Resolution	X
1	Will team be cross trained?	I						
2	What will project life be?	E						
3	Can takt time goal be met?	A						
4	Must use avail. Equipment	A						
5	Must start delivery by 11/15	A						
6								
7								
8								
9								
10								

Dominance/Importance Rating Mark "X" if beyond control of company/plant/project
 Notes: _____

Distribution Team By Team With DM Status as of _____

PROJECT SCHEDULE

No	Action Required	Who	10/8	10/15	10/22	10/29	11/5	Notes
1	Define & schedule project	Team						
2	Classify parts	BG						
3	Analyze & document process	PH						
4	Balance operations	PH						
5	Equipment & Flow Diagram	PH						
6	Develop cell plans	Team						
7	Evaluation meeting	All						
8	Make implementation plan	DM						
9	Install available equipment	DM						
10	Complete implementation	All						Target 11/15

Notes: _____

Figure 2. Cell Planning Orientation & Issues Worksheet for a small cell assembling sheet metal ovens. © Copyright 1995 Richard Muther.

Less common but occasionally significant classification factors include building features, safety issues, regulatory considerations, marketing-related considerations, and even organizational factors that may be reflected in the way that a specific part is scheduled and produced.

All of these factors can be tied together into a worksheet like the one shown in Figure 3.

PRODUCT/PART CLASSIFICATION WORKSHEET		Project <u>Oven Assembly Cell</u>										Project No. <u>99509</u>												
		By <u>BG</u>					With <u>Team</u>					Date <u>10/9</u>		Sheet <u>1</u> of <u>1</u>										
Item No.	Name	Basic Material	Physical Characteristics							Other Considerations*										Further Explanation	Class. Identif.			
			Quality Level	Size	Weight-Density	Shape	Risk of Damage	Value	Q	R	S	T	B	F	L	K	O							
A	Top Half	Steel	O	E	8	"U"	O					1	O	U	O	U	U	U						b
B	Lower Half	Steel	O	E	8	"U"	O					1	O	U	O	U	U	U						b
C	Coil Holders	Steel	O	O	4	"I"	O					2	O	U	O	U	U	U						d
D	Thermo Bracket	Steel	O	O	4	"I"	O					1	O	U	O	U	U	U						d
E	Nut	Steel	O	O	2	"H"	O					1	O	U	O	U	U	U						d
F	Back	Steel	O	I	8	"F"	O					1	O	U	O	U	U	U						c
G	Reinforcements	Steel	O	O	3	"FL"	O					2	O	U	O	U	U	U						d
-	Oven Assembly	Steel	O	A	44	"R"	I					1	O	U	O	U	U	U						a

<p>* Other Considerations</p> <p>Q Quantity/Volume/Demand F Safety problems R Routing/Process domination L Legal/Regulatory problems S Service/Utility requirements K Market togetherness T Timing/Complementary seasons O Others/Operators/Organization B Building features</p>	<p>Reference Notations</p> <p>a. <i>Weight shown in ounces</i> _____ b. <i>Finished assembly: 24" x 19" x 16"</i> _____ c. <i>Number of pieces per unit</i> _____ d. _____ e. _____</p>
---	--

Figure 3. Product/Part Classification Worksheet for the parts sketched in Figure 4. © Copyright 1995 Richard Muther.

The planner identifies and records the physical characteristics and other considerations for each part or item. If it seems awkward to record or rate each amount or specific dimension, one can rate the importance or significance of each characteristic as to its contrast or dissimilarity with the other parts. Use the vowel-letter, order-of-magnitude rating code illustrated in Figure 3 and defined below.

- A – Abnormally great
- E – Especially significant
- I – Important
- O – Ordinary
- U – Unimportant

After recording or rating the physical characteristics and other considerations for each part or item, note those parts that have similar characteristics – that is, classify the parts according to the most important characteristics and considerations. Assign a class code letter to each class, group, or combination of meaningful similarities. Enter the appropriate class letter code for each part or item in the Class Identification column.

When a large number of different parts will be produced, planners should place special emphasis on sorting the parts into groups or sub-groups with similar operational sequences or routings. Those assigned to a class will all go through the same operations. Generally, for cells producing many parts different parts, this is the most useful type of classification for the subsequent steps in cell planning. The final output of Step 2 – Classify the Parts is a clear listing of the classes or groups of parts to be produced in the cell.

Step 3. Analyze the Process

In Step 3, the planner uses charts and diagrams to visualize the routings for each class or sub-group of parts, and then calculates the numbers of machines and/or operators and work places that will be required to satisfy the target production rates and quantities.

If the cell performs assembly – like that of the sheet metal oven shown in Figure 4 – the best way to visualize the process is with an operation process chart like that shown in Figure 5.

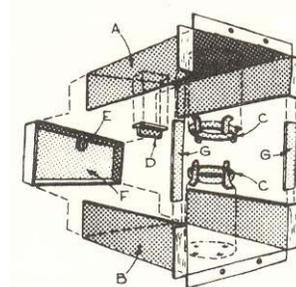


Figure 4. Sketch of the sheet metal oven charted in Figure 5. The oven consists of a top half, a bottom half, and a back, to which smaller parts are added.

In addition to showing the progressive assembly of the finished item, the process chart also shows the labor time at each step. Given a target production rate and the number of working hours available, the planner calculates the work content of the process and breaks it into meaningful work assignments. In this way, the required number of operators and workplaces is determined, along with the flow of materials between them. Assumptions or calculations must be made to establish the time that will be lost to breaks and to “non-value adding” tasks such as material handling, housekeeping, and the like. The formal name for this process is line balancing. A good line balance achieves the desired production rate with the minimum number of operators and minimal idle time.

Once balanced to the planning team’s satisfaction, workplaces and equipment are defined and represented in an Equipment and Flow Diagram. This is the final output of Step 3. See Figure 6. In this example, scaled templates represent the equipment. Such graphic detail is useful but not mandatory. A simple square symbol can be used to represent each operator workstation, or each machine. Numbers of lines and lower-case letters designate the flow of parts and materials.

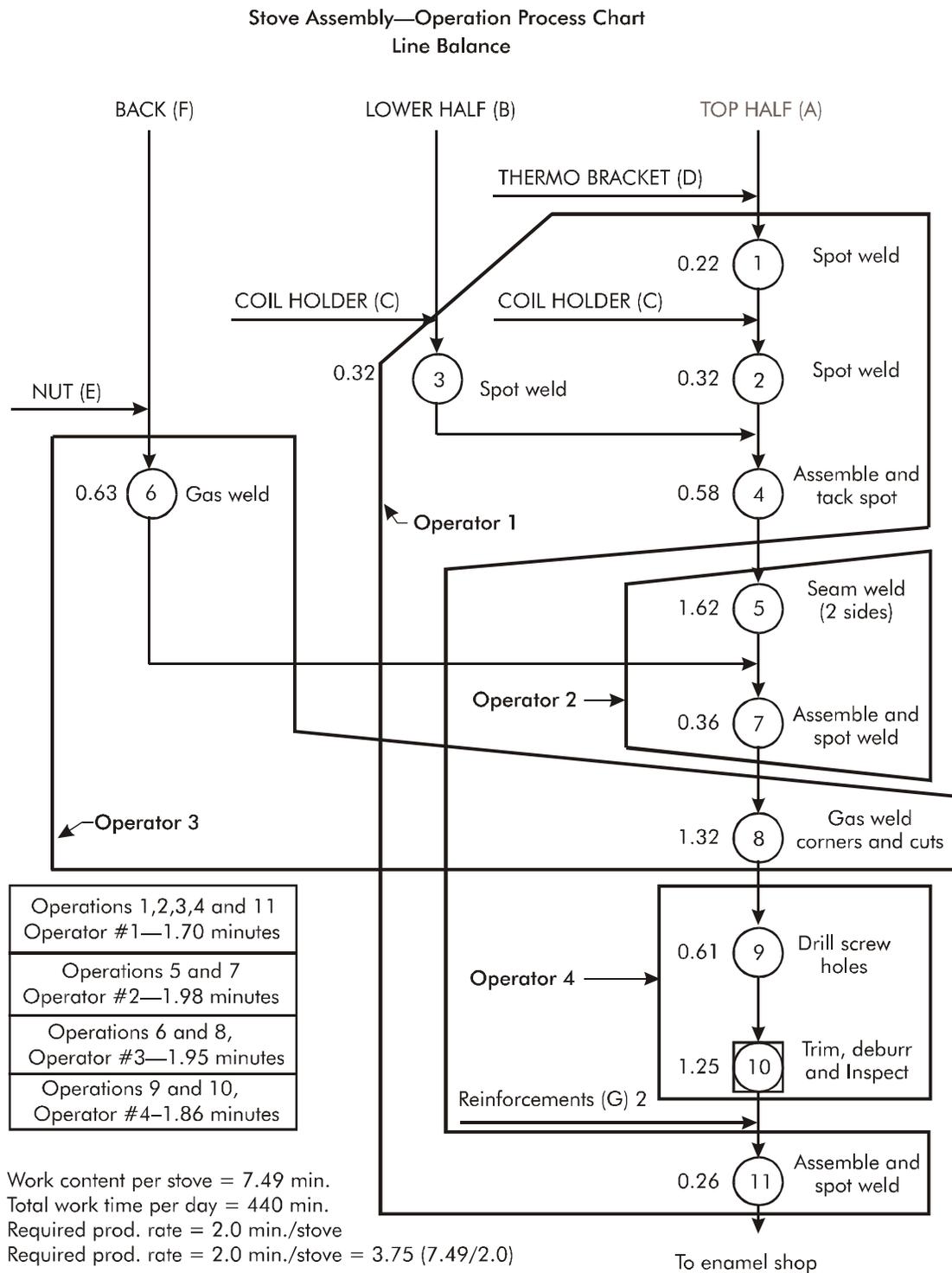


Figure 5. Operation Process Chart for the sheet metal oven pictured in Figure 4. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

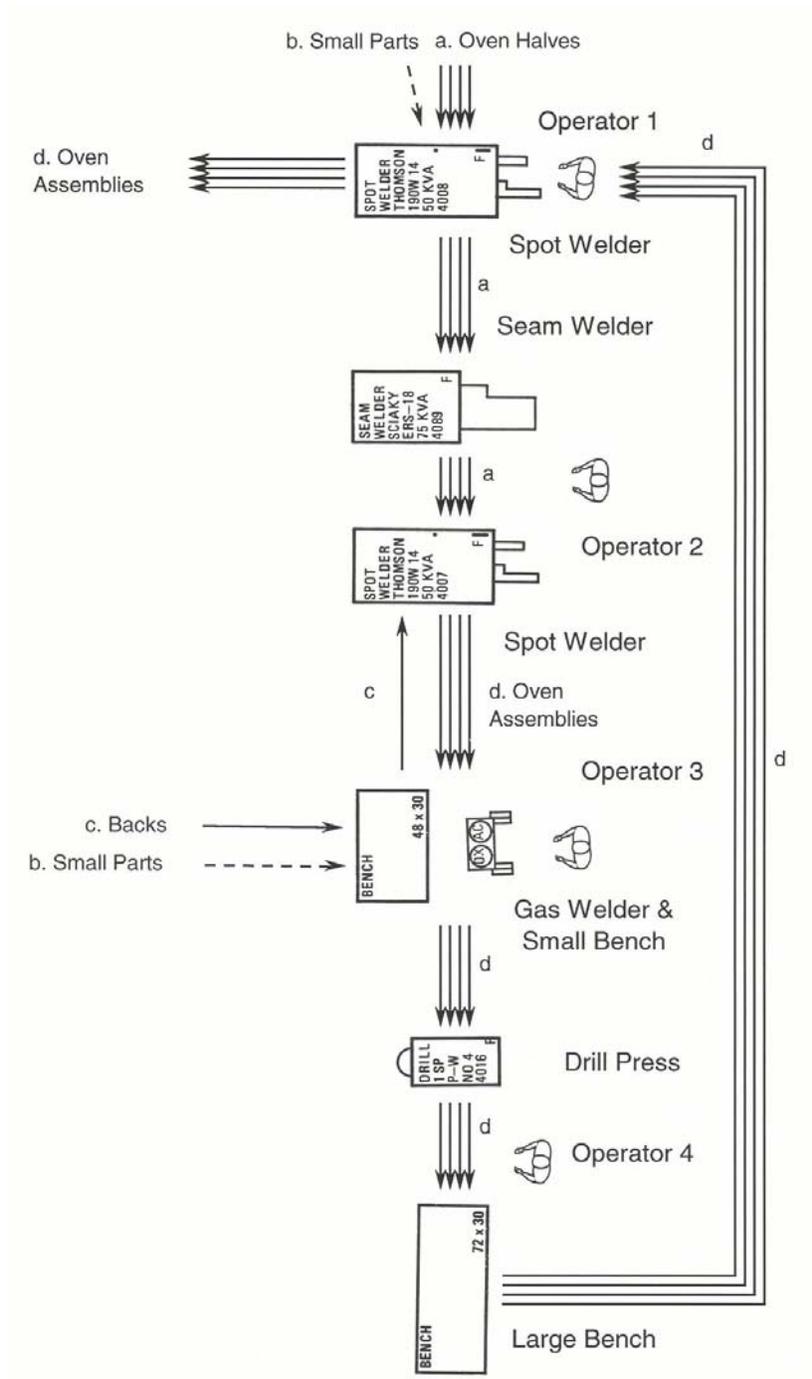


Figure 6. Equipment and Flow Diagram for the sheet metal oven charted in Figure 5.

When planning a machining or fabrication cell, the Group-of-Parts process chart is used to illustrate the sequence of operations for each class of parts. See Figure 7.

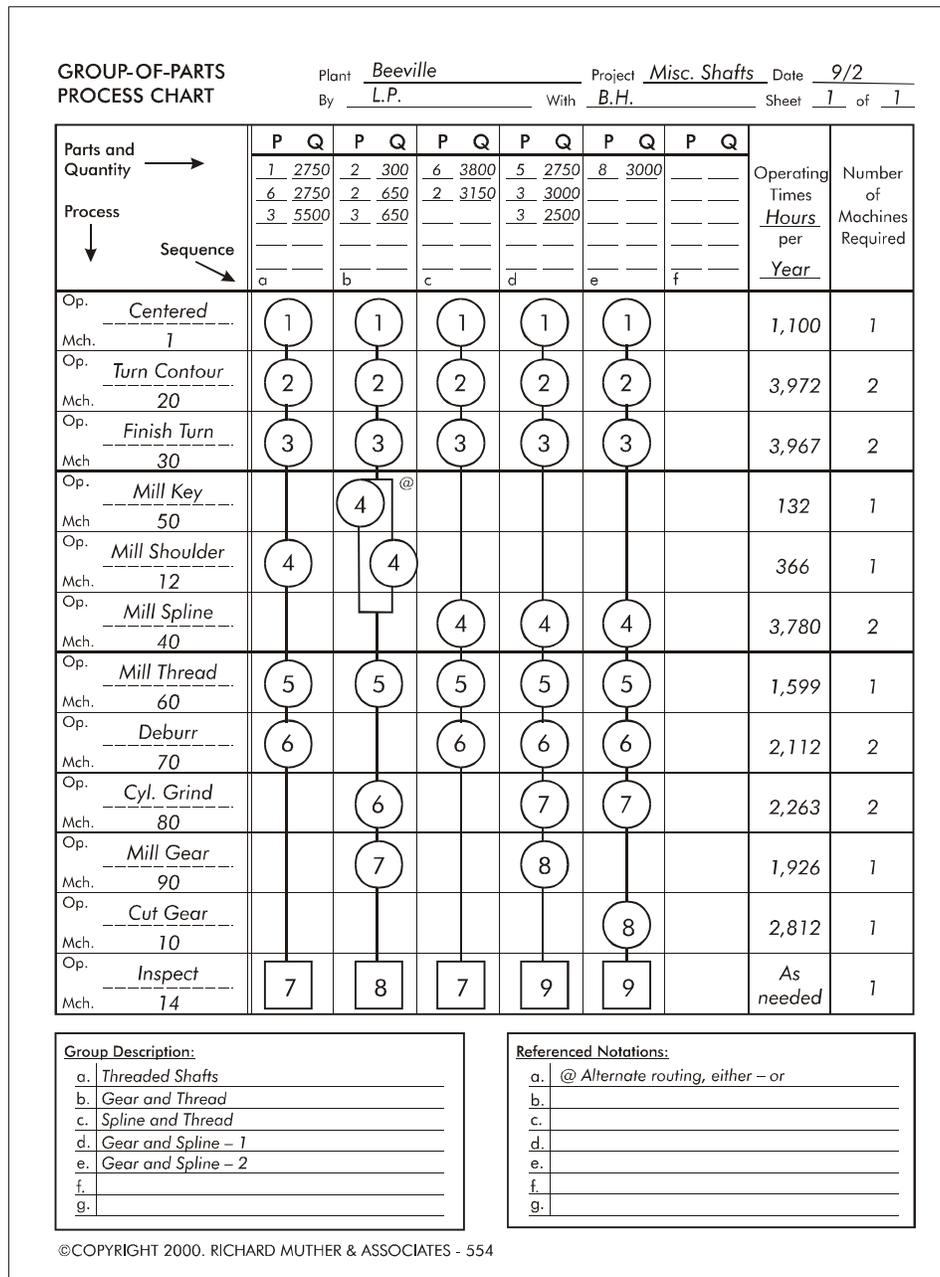


Figure 7. Group-of-Parts Process Chart for a family of steel shafts. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

The Group-of-Parts process chart must be accompanied by a capacity analysis showing the types and quantities of machines required by the cell. A simple form of this capacity analysis is shown in Figure 8.

PRODUCT CLASS/DESCRIPTION	Work Center Number>>			MACHINE TYPE										
				1	20	30	50	12	40	60	70	80	90	10
	Part No.	Model	Pieces per Year	Center'g Lathe	Contour Lathe	Engine Lathe	Key Mill	Univ. Mill	Spline Mill	Thread Mill	Drill Press	Cylinder Grinder	Gear Mill	Gear Cutter
Carried forward from Page 2 (hours/year)				750	2192	2775	0	0	3521	718	838	1585	1563	1750
(b) Shaft with gears and threads														
Rear axle gear shaft	47345 53049	LS 20 B 30	300	8	55	28	---	15	---	15	---	123	15	---
Power take-off shaft	36456 70459	L 10 L 20	650	13	108	32	---	18	---	43	---	132	39	---
Auxiliary gear shaft	56097 78905 76890	LS 20 B 20 B 30	650	13	135	74	120	---	---	67	---	149	32	---
(a) Shaft with threads														
Injection pump drive shaft	46785	M 85	2750	42	335	255	---	22	---	205	275	---	---	---
Steering knuckle arm	46056 45159 45907 45650 45432 45329	L 10 BH 10 L 20 BH 20 BV 20 B 30	2750	46	160	225	---	168	---	182	463	---	---	---
King pin	46554 56354 10101	L-B 10 L-B 20 B 30	5500	92	350	275	---	92	---	228	245	---	---	---
Machine Run Time (hours/year, incl. load & unload)				964	3335	3664	120	315	3521	1458	1821	1989	1649	1750
Setups (estimated hours per year)				100	600	260	3	30	210	111	21	200	200	522
Scheduled Maintenance (est. hrs per year)				24	25	28	6	14	33	20	180	50	52	360
Allowance for Unplanned Downtime (est. hrs per year)				12	12	15	3	7	16	10	90	24	25	180
Total Machine Hours Per Year				1100	3972	3967	132	366	3780	1599	2112	2263	1926	2812
No. of Machines Required				0.6	2.0	2.0	0.1	0.2	1.9	0.8	1.1	1.1	1.0	1.4
No. of Machines Available				1	2	2	1	1	2	1	2	2	1	1
Capacity Utilization				55%	99%	99%	7%	18%	95%	80%	53%	57%	96%	141%

Figure 8. Capacity Utilization Worksheet for the family of steel shafts charted in Figure 7. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

When calculating the number of machines, planners must be sure to add allowances to downtime, schedule interference, and changeovers between individual parts and groups of parts.

A good cell capacity plan meets the desired production rate with an appropriate number of machines and level of utilization. Usually, the analysis will reveal over and under-utilization of some equipment planned for the cell. If the analysis reveals over-utilization, the planner may choose to:

- Remove parts from the cell to reduce utilization of the equipment.
- Purchase more equipment.
- Reduce process, changeover, or maintenance times.

If the analysis reveals under-utilization, the planner may choose to:

- Add parts to the cell to increase the utilization of equipment.
- Remove parts from the cell to eliminate the need for the equipment.

- Change the manufacturing process to eliminate the need for the equipment.
- Leave the equipment external to the cell and route parts to it.

In machining or fabrication cells where the throughput is paced more by the operators than the machines, the cell planner may need to conduct a line balancing exercise, in addition to rough capacity and utilization analyses. In some cases, computer simulation may be useful to examine the implications of changes to product mix and peaks in production volume.

Once the number of machines has been determined, an Equipment and Flow Diagram is prepared, similar to that shown earlier in Figure 5. The Standardized Work form shown in Figure 9 is a similar type of conceptual visualization that also illustrates operator times and cycles.

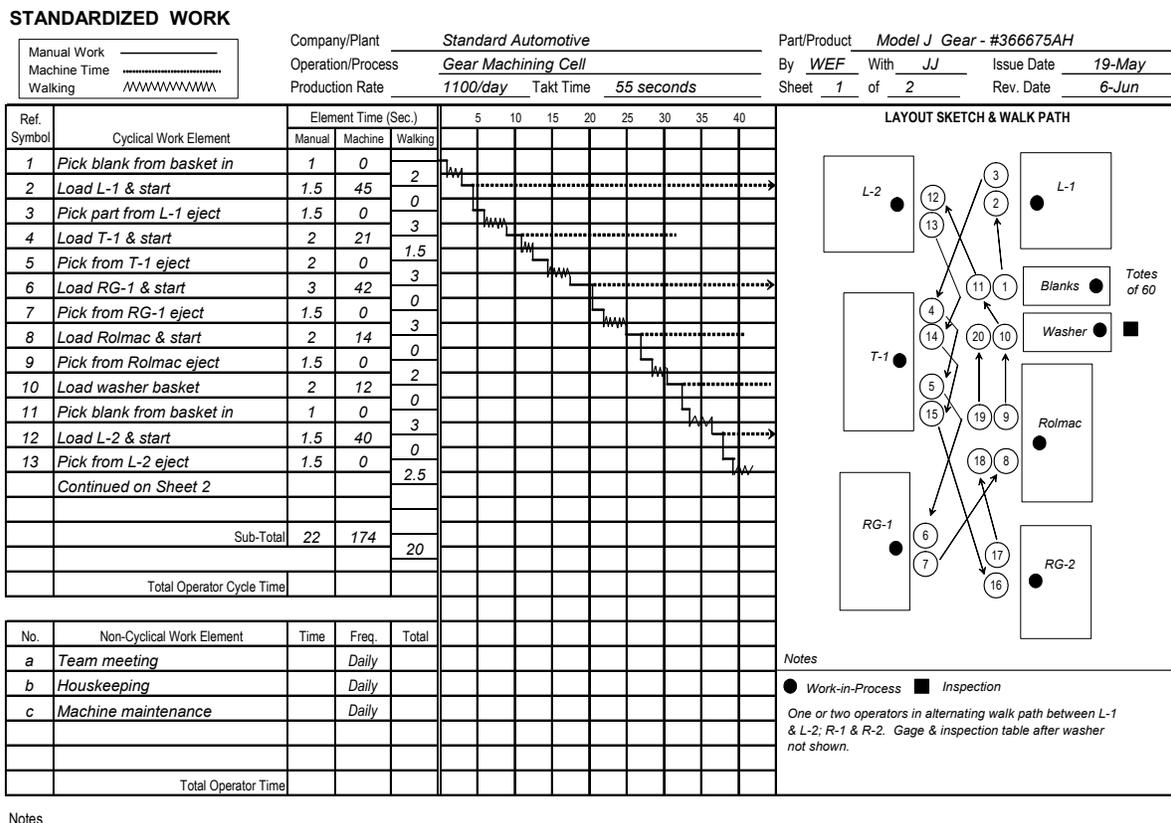


Figure 9. Standardized Work for a gear machining cell. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

Step 4. Couple into Cell Plans

A cell plan is a coupling of parts and process into an effective arrangement and operating plan. It should include:

- The layout of operating equipment (physical)
- The method(s) of moving or handling parts and materials (physical)
- The procedures or methods of scheduling operating, and supporting the cell (procedural)
- The policies, organizational structure, and training required to make the cell work (personal)

The best way to begin this step is by sketching a layout from the Equipment and Flow Diagram developed in Step 3. Once the machinery and workplace layout is visualized, the material handling and any storage methods are determined. Material handling equipment, containers and storage, or parts-feeding equipment are added to the layout. The planner also adds any support equipment not already visualized in the workplaces, such as tool and die storage, fixture storage, gage tables and tool set-up, inspection areas, supply storage, trash bins, desks, computer terminals and printers, display boards, meeting areas, etc.

Once the layout and handling methods – the physical aspects of cell planning – have been determined, the planning team turns its attention to the procedural and personal aspects. In our experience, the procedural and personal aspects are often more important than the layout and handling in assuring a successful manufacturing cell. These aspects include the procedures and policies for staffing, scheduling, maintenance, quality, training, production reporting, performance measurement, and compensation. In practice, some of these will have already been determined during the layout and handling discussion; the remainder should be clearly defined by the team and approved by management. The documentation of a viable cell plan will also require the resolution of any remaining planning issues listed earlier in Step 1. The final output of Step 4 is one or more documented cell plans. These will take the form of a layout with associated policies and operating procedures like that shown in Figure 10.

Step 5. Select the Best Plan

In Step 5, the planning team and other decision-makers will evaluate the alternatives prepared in Step 4 and select the best plan. Typically, this selection will be based upon comparisons of costs and intangible factors. Typical considerations include:

Investment costs (and savings or avoidance)

- New production machinery
- Material handling equipment
- Pallets, containers, and storage equipment
- Auxiliary or support equipment
- Building or area preparation

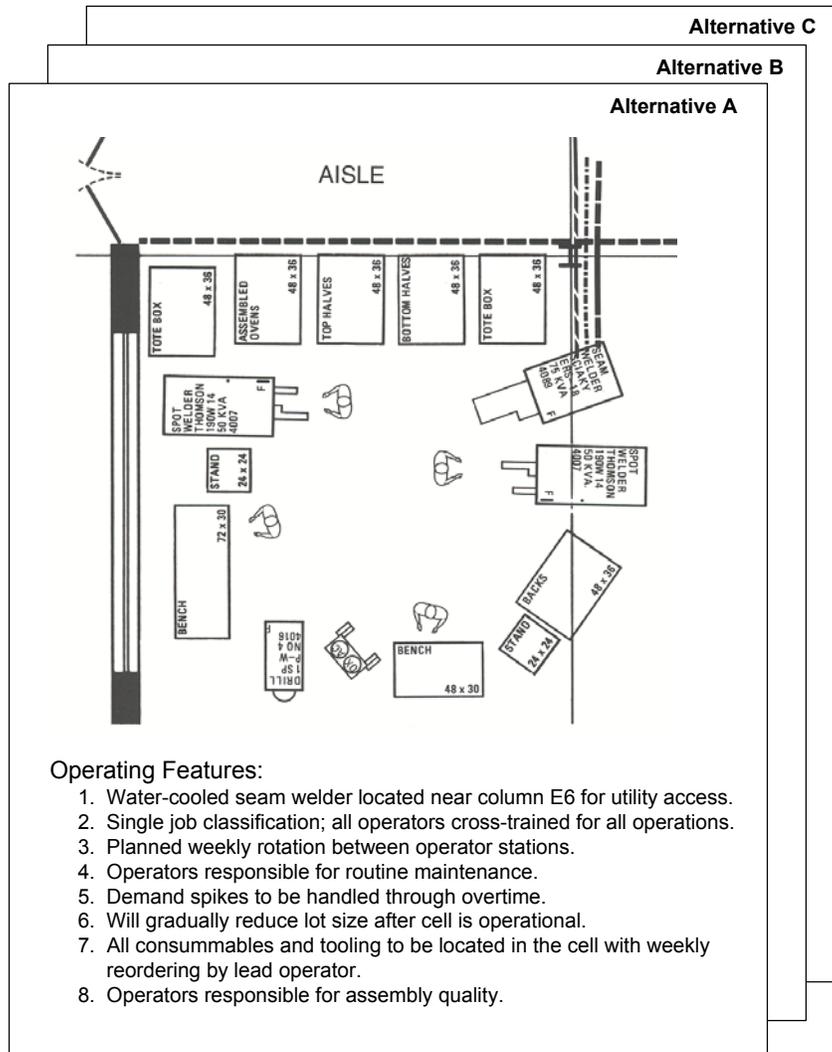


Figure 10. Alternative cell plans for the oven assembly cell diagrammed in Figure 6.

- One-time move costs, including overtime
- Training and run-in
- Engineering services
- Permits, taxes, freight or other miscellaneous costs
- Inventory increases or reductions (one-time basis)

Operating Costs

- Direct labor
- Fringe benefits and other personnel-related costs
- Indirect labor
- Maintenance

- Rental of equipment or space
- Utilities
- Inventory increases or decreases (annual carrying cost)
- Scrap and rework

Intangible Factors

- Flexibility
- Response time to changing production demand
- Ease of supervision
- Ease of material handling
- Utilization of floor space
- Ease of installation (avoidance of disruption)
- Acceptance by key employees
- Effect on quality

Costs are rarely sufficient for selecting the best cell plan. There are typically too many intangible considerations involved. And in many cases, the costs of alternative plans fall within a relatively narrow range. In practice, the final selection often rests on intangibles.

The weighted-factor method is the most effective way to make selections based upon intangible factors. After making a list of the relevant factors, weights should be assigned to indicate their relative importance. An effective scale is 1 to 10: with 10 being most important. Next, the cell operating team should rate the performance or effectiveness of each alternative on each weighted factor. It is important that ratings be made by cell operators and the appropriate plant support personnel – those closest to the action and responsible for making the selected plan work.

Since ratings are subjective they are best made with a simple vowel-code scale, and converted later into numerical values and scores. The following scale and values are effective:

A – Almost Perfect Results (excellent)	4 points
E – Especially Good Results (very good)	3 points
I – Important Results (good)	2 points
O – Ordinary Results (fair)	1 point
U – Unimportant Results (poor)	0 points
X – Not Acceptable Results	fix or remove from consideration

Rating values are multiplied by factor weights and down totaled to arrive at a score for each alternative plan. If one plan scores 15% to 20% higher than the rest, it is probably the better plan. If the costs are acceptable, this plan should be selected. If no plan scores significantly better than any other, then pick the least expensive, or consider additional factors. The final output of Step 5 is a selected cell plan.

Step 6. Detail and Implement the Plan

Once selected, details must still be worked out and preparations made to implement the cell plan. Detailing should begin with an updated, dimensioned drawing of the selected cell layout – typically at a fairly large scale, say 1:50. The detailing step should produce a scaled plan view of each work place showing:

- Normal operator work position
- Location of tooling, gauges, controls
- Parts containers, fixtures, and workplace handling devices
- Utility drops and connection points
- Door swings and access points on control panels and machinery
- Position of overhead lighting

In some cases, an elevation sketch may be useful, showing vertical placement of work surfaces, fixtures, containers, etc. Where highly fixed machinery is tied together with fixed conveyors, or where robots are used, it may also be necessary to develop a 3-dimensional computer model of the cell in order to simulate or test for interference and proper placement.

In light manufacturing cells – machining or assembly – where equipment is easily adjusted during installation, this sophistication is typically unnecessary. Conventional plan views are usually sufficient.

If space is available and time permits, great insight can often be gained by creating a life-size mock-up of the cell, using cardboard, wood, light metal or plastic tubing. (See Figure 11). By involving the cell operators in this mock-up, a great deal of useful detailing can be accomplished in a very short time. In our experience, mock-ups provide two significant benefits: (1) They uncover overlooked details that may be expensive to change later in implementation, and (2) they obtain a much greater level of operator involvement and interaction than is possible with an on-screen computer model, or with a 2-dimensional plan view of the layout.

Implementing a cell is an opportunity on a relatively small scale to make progress on plant-wide improvement initiatives. The cell implementation plan should include tasks, time, and money for the following common improvements:

- Housekeeping & safety – disposition of unnecessary items, fixing of leaks, cleaning and painting of machines, floors, ceilings, machine guards, aisle way guard rails and posts, etc.
- Visual Control – marking and striping, signs for machines and workplaces, labeling for tool and fixture storage and containers, signal lights, performance displays.
- Quality Management – certification of machine and process capabilities, tool and gauge lists and calibration plans, mistake-proofing and failure analyses, control plans, training, etc.



Figure 11. Physical mock-up for the gear machining cell charted in Figure 9. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

- Maintenance -- repair and rebuilding of machines, replacement of worn-out equipment, preventive maintenance schedules, operator maintenance procedures, etc.
- Set-Up Reduction – video-taping, time- study, and methods analysis; redesign of fixtures, tools, and machines; duplication of key equipment, gauges, and fixtures, redefinition of responsibilities; training, etc.

Once the necessary tasks have been defined, they should be assigned to the appropriate individuals, estimated in terms of time and resources, and placed into a schedule, recognizing any dependencies between the tasks. The final output of Step 6 is the selected cell plan detailed and ready for implementation.

MORE COMPLEX CELLS

Several considerations can complicate cell-planning projects. Chief among these is the question of how many cells are needed. Given a set of candidate parts and their desired production rates or quantities, the planner must occasionally decide whether a single cell is appropriate, or whether the work should be spread across multiple cells.

When one or more cells feed others, the project becomes one not unlike planning a “mini-factory.” (See Figure 12). Additional analysis is required to agree upon the material-handling methods and scheduling procedures for moving parts *between* the cells. It may also be necessary to share personnel or equipment capacity *across* the cells being planned. And, the project may also have to decide on common policies (across all of the cells) for organization, supervision, and performance measurement.

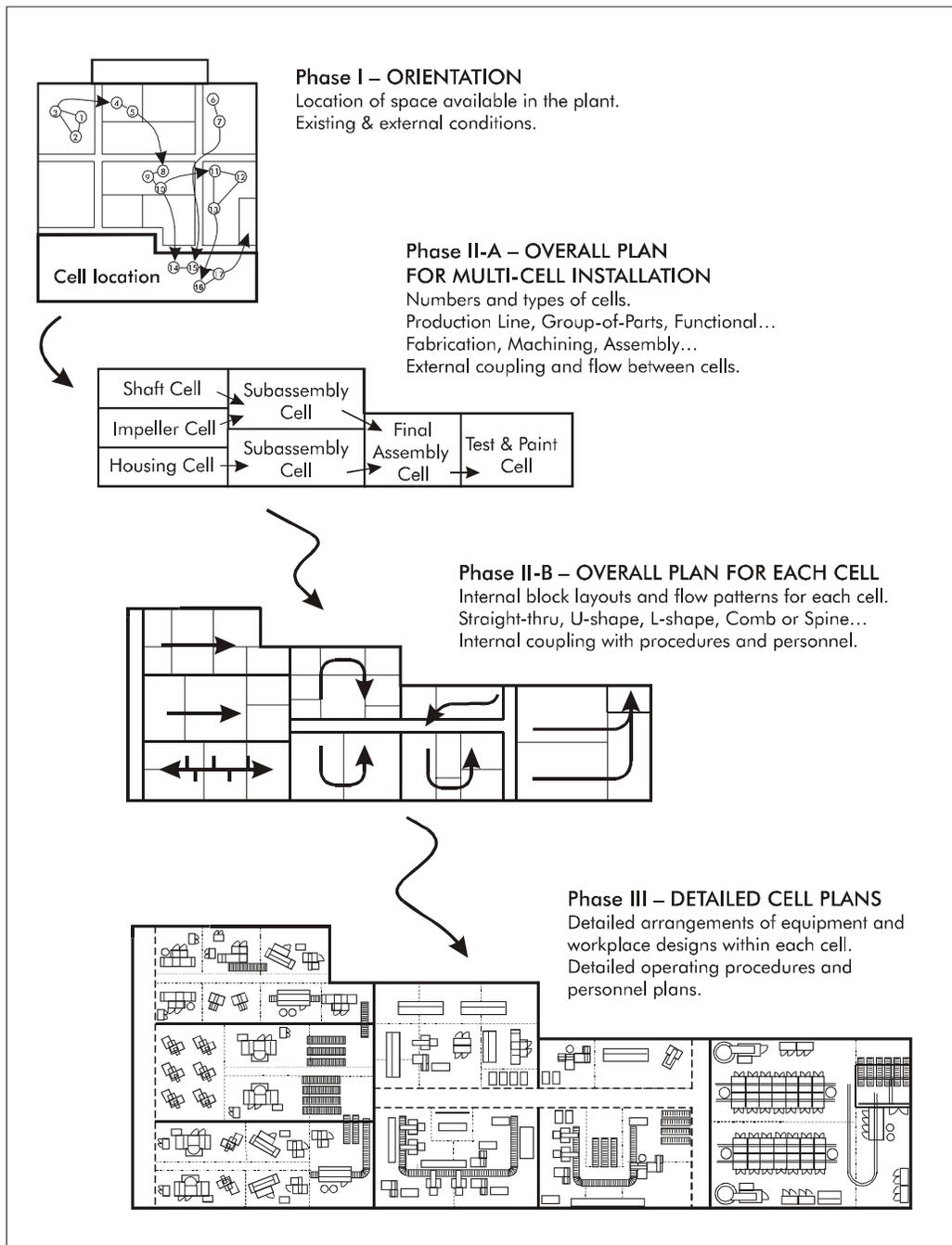


Figure 12. Complex, multi-cell planning. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

Even when planning a single cell, complications can be introduced if there is a wide range of possible locations for the cell, the appropriate level of automation is unclear, or there is the potential for radical organizational change, such as a move from traditional supervision to self-directed teams.

Four Phased Approach

Complex cell planning projects are best planned in four overlapping phases.

- I. Orientation
- II. Overall Cell Plan
- III. Detailed Cell Plans
- IV. Implementation

The scope of these phases is illustrated in Figure 13. Specific steps within each phase are fully-described in the book: *Planning Manufacturing Cells*, by H. Lee Hales and Bruce Andersen. See Reference 3. A synopsis of each phase is presented here.

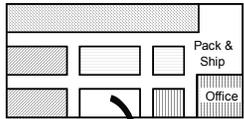
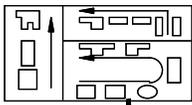
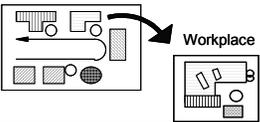
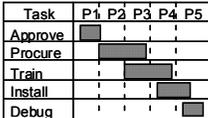
Planning Phases	Scope & Visualization	Outputs
I. ORIENTATION Location, external conditions and planning the planning. The surrounding physical and non-physical conditions/considerations; plus the objective, situation and plan for planning the cell.	The Plant 	<ul style="list-style-type: none"> Objectives Project plan & schedule Targeted parts or operational area Planned location External conditions Scope; "givens", or limits of team's authority
II. OVERALL CELL PLAN The general plan for cellular operations. Definition of the cell or cells: how many; what parts, what processes and equipment. Alternative block layouts of space and equipment. Operating relationships and integration between cells and the rest of the plant.	Manufacturing Cells 	<ul style="list-style-type: none"> Definition of cells: what parts, what operations, what equipment Block layout of cells and supporting areas Material handling and coupling between cells Preliminary cell layouts General operating policies and practices
III. DETAILED CELL PLANS Detail plans and designs for each cell. The detailed arrangements of equipment and workplace design. Specification of detailed operating procedures and methods within each cell.	Cell or Subcell 	<ul style="list-style-type: none"> Confirmed definition of cell: parts, operations, equipment Detailed layout for each cell Material handling within the cells (between work stations) Detailed operating policies and procedures
IV. IMPLEMENTATION Do; take action on the plans. Schedule, provide, procure, train, install, cleanup, debug...		<ul style="list-style-type: none"> Project approval and funding Detailed implementation plan Procured equipment Working cell

Figure 13. Four phases for planning complex cells. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

Phase I – Orientation

Complex projects or those with very large scope may need an entire phase to determine the best location(s) for the prospective cell(s), the handling to and from, the issues involved, and the plan for planning the cell. Reaching sound decisions may require creating or updating a master plan for the total facility. It may also require some conceptual planning of the prospective cells themselves – hence the overlap with Phase II – Overall Cell Plan.

Phase II – Overall Cell Plan

In large or complex planning projects, Phase II defines the general plan for cellular operations. This includes the number of cells and their respective parts and processes, and the relationships between them. Block layouts are developed along with material handling plans for movement to and from and in between the cells. General operating practices or policies are decided. These planning activities and decisions are not addressed in the simplified six-step approach described in the previous section, How to Plan a Manufacturing Cell. Reaching decisions in Phase II may also require some detailed planning and design – and therefore overlaps Phase III – Detailed Cell Plans.

Phase III – Detailed Cell Plans

Phase III details the individual cell(s) within the selected overall plan. The six-step simplified procedure described in the previously is highly effective for purpose. At the conclusion of Phase III, the planning team has identified the best detailed plan for each manufacturing cell.

Phase IV – Implementation

In Phase IV, an implementation schedule is defined for each cell. On larger and complex projects involving multiple cells, this schedule may span several months. It will typically include many interdependencies between the individual cell installations, and changes to the surrounding facilities, organization, and management systems. The team then obtains approval and funding, procures necessary equipment and services, directs the physical and procedural implementation, and debugs and releases the cell for production.

Impact of Automation & Technology

Most manufacturing cells consist of conventional, operator-controlled machinery and equipment. However, in some industries and processing situations, highly automated machinery may be used. For example, cells for high volume, repetitive welding may use robots instead of human operators. The same is true with other hazardous operations such as forging. In high volume assembly of many small or precision components, cells may consist of automated assembly machines, and pick-and-place robots, often connected by conveyors. The entire cell may be computer controlled, with operators providing service and material handling to and from the cell. In some cases, the material handling may be automated using automated guided vehicles.

In between the extremes of all manual or fully automatic operations, cells may include some limited automation for parts feeding and loading, or material handling between operations. A common example is the use of automatic ejection or unloading devices on machine tools. These are typically used to present a completed part to the operator during the same cycle used to manually load the machine. Other examples of selective automation include conveyORIZED parts washers, curing tunnels, or similar process equipment. Typically the conveyor automates movement between sequential operations without operator intervention or effort, and may drop finished parts into a container.

If an automated cell with computerized controls is planned, extra attention should be given to estimating the costs of equipment, software, systems integration, and to the ongoing maintenance of the system. Adherence to sound technical standards and thorough documentation of all computerized systems will help to keep these costs down. As noted earlier, advanced visualization with 3-dimensional computer models is often valuable. Computer simulation may also be used.

Use of automation and advanced technology in a manufacturing cell is most appropriate when the following conditions apply:

- Production volumes are very high, typically above 500,000 units per year, and predictable or steady.
- Product lives are relatively long (before extensive changes or reconfigurations are required).
- Product designs are relative stable.
- Labor is expensive.
- The company or plant has prior successful experience with automated systems.
- The processes are hazardous or unsafe for human operators.
- Very high repeatability and precision are required.
- The processing technology is stable.

When several of these conditions are met, then at least one alternative cell plan should make use of automation, to be sure that good opportunities are not overlooked.

CHECKLIST FOR CELL PLANNING AND DESIGN

Pages 23 - 27 contain a checklist and brief discussion of the most common choices or decisions to be made when planning or designing a cell. The topics are organized around the three aspects of cell planning discussed earlier: physical, procedural, and personal. The order of presentation follows roughly the order in which the choices and decisions should be made during a planning project – starting with the physical, followed by the procedural, and finally the personal or personnel-related.

A more detailed and formatted version of this checklist may be downloaded in Microsoft Excel format from www.hpcinc.com/rma.html. (Navigate: Downloads>Register>Form 760 1-4, Manufacturing Cell Planning Coupling & Integration Worksheet.)

Physical Questions

Layout and Flow Patterns

1. Which material flow pattern should be used within the cell?
 - a. Straight-through
 - b. U-shaped
 - c. L-shaped
 - d. Comb or spine

Cells may be physically arranged into one of four basic flow patterns. (See Figure 14). While the U-shape is frequently advocated and very common, the other patterns do have occasional advantages and appropriate uses. Your authors believe that the best cell layouts are achieved when the planning team forces itself to consider at least two alternative flow patterns, if only to stimulate discussion.

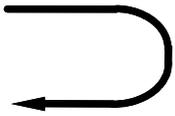
Basic Cell Flow Patterns and Their Benefits	
<p>Straight Thru</p> 	<ol style="list-style-type: none"> 1. Easy to understand, follow, schedule, and control. 2. Allows straight, inexpensive handling methods. 3. Easy access on two sides. 4. Avoids congestion at point of delivery and take away.
<p>U-Shape or Circular</p> 	<ol style="list-style-type: none"> 1. Automatically returns product, holding fixtures, and mobile handling equipment to cell entrance. 2. Delivery and take away point are the same; allows convenient handling to and from the cell. 3. Workers in center can assist one another more readily. 4. Easier to assign multiple operations to an operator. Allows easier line balancing.
<p>L-Shape</p> 	<ol style="list-style-type: none"> 1. Allows fitting lengthy series of operations into limited space. 2. Lets feeding cells start on an aisle and end at point of use. 3. May allow isolation of dangerous or costly-to-move equipment in the elbow, with savings in implementation cost and/or two directions for expansion. 4. Easy to segregate in-flow and out-flow of physically different materials, products, supplies, and special services.
<p>Comb or Spine</p> 	<ol style="list-style-type: none"> 1. Lends itself to two-way flow. 2. Well suited to cells with highly variable routings. 3. Allows "fingers/teeth" to be segregated for special requirements. 4. Well-suited to functional cells.

Figure 14. Basic cell flow patterns. From the book: *Planning Manufacturing Cells*, © Copyright 2002 Richard Muther & Associates.

2. How does the choice of flow pattern fit with the overall plant layout and material flow? When deciding on the internal flow pattern for each cell, do not overlook its relationship to and impact upon the overall plant layout. The layout of aisles and general flow pattern in the factory may favor or even force a particular flow pattern within the cell.

Handling and Storage

1. What are the groups or classes of material to be moved? General categories to be examined include:
 - a. Incoming parts and materials to the cell
 - b. Work in process between workstations within the cell
 - c. Outgoing parts and materials leaving the cell
2. Classes should be defined with an eye toward common handling and storage methods. The classes for work-in-process should have already been defined through parts classification and analysis of the process. But a review of incoming and outgoing parts and materials may introduce additional classes, not yet identified or considered.
3. What handling equipment should be used for each class of material? Typical choices include: forklifts, tugs and carts, push-carts, walkie pallet jacks, conveyors, slides, chutes, overhead handling devices, or simply the operators themselves, hand carrying parts or materials.
4. What containers or transport units will be used? Typical choices include pallets, skids, bulk or large containers, small containers and totes, cartons, or in some cases, the items themselves.
5. Where and how will materials be stored or staged? What equipment will be used? Typical choices include: the floor, flow racks, shelves, pallet racks, cabinets, cartridges or magazines integrated directly into machines, or directly on work benches themselves.
6. How much material will be staged or stored? Typically expressed in minutes, hours, or days of coverage at an expected production rate.
7. How much staging or storage space will be required? And where should it be placed in the layout?

Supporting Services & Utilities

1. What process-related supporting services are required? Space and equipment are often required for tool & die storage, fixture storage, gage tables and benches, tool set-up, inspection areas, supplies, trash, and empty containers.
2. What personnel-related supporting services are required? Typical include: shop desks and work areas; team meeting area; computer terminals and printers, telephones and public address speakers, document storage, bulletin boards, etc.

3. What special utilities are required? Water and drains? Special electrification? Special ventilation or exhausts? Lighting?

Procedural Questions

Quality Assurance/Control

1. Who will be responsible for quality? Will operators inspect their own work? Each other's work? Or, will dedicated inspectors be used? From within the cell or from outside?
2. What techniques will be used? e.g. visual, statistical process control, mistake proofing, etc.
3. Will special equipment be required?
4. What specifications or procedures are relevant or should be incorporated into the plan?

Engineering

1. Who is responsible for engineering the parts and processes involved?
 - a. Product engineering
 - b. Manufacturing/process/industrial engineering
3. How will tooling be managed? Externally by a central organization, or internally within the cell? Will tools be shared or dedicated to each machine?
4. Where will tools be stored? External to the cell? Internal? Centrally or at each work place or machine?
5. Who will be responsible for set-up? External or internal specialists? Operators themselves? Teams?

Materials Management

1. How will production be reported? Aggregate or total units only? Each unit as completed? First and/or last operation as performed? At the completion of each operation?
2. How will reporting be accomplished? Using paper forms? Key entry? Bar code scanning or other electronic method?
3. How will the cell be scheduled and by whom?
4. How will specific parts and jobs be sequenced? Who will be responsible?
5. Is line balancing needed?

6. What is the strategy for workload and capacity management? How will the cell respond to changes in product mix, bottlenecks and peaks?
 - a. With extra, idle machine capacity?
 - b. With extra labor or floating personnel?
 - c. With overtime?
 - d. With help from adjacent cells?
 - e. By off-loading work?
 - f. By building ahead to inventory?
 - g. By rebalancing or reassigning operators?

Maintenance

1. Who will be responsible for maintaining machinery and equipment? External by a central organization, or internally by cell operators?
2. Have specific maintenance duties and frequencies been defined?
3. Who will be responsible for housekeeping? Cell operators or external personnel?
4. Are preventive maintenance procedures required?
5. Are statistical or predictive maintenance procedures appropriate or necessary?
6. Will the cell require special equipment or services to hold or recycle waste, chips, oils coolant, scrap, etc?

Accounting

1. Will new accounting or reporting procedures be required? For costs? For labor? For material usage?
2. Will the cell be treated as a single work or cost center for reporting purposes? Or, will costs be charged to specific operations within the cell?
3. Will labor reporting distinguish between direct and indirect activities?
4. Will labor be reported against specific jobs or orders?
5. Will inventory be charged or assigned to the cell? Will the cell be a controlled inventory location?
6. How will scrap and rework be tracked and reported?

Personnel-related Questions

Supervision & Performance Measurement

1. Will the cell have a designated supervisor or team leader? Or will the cell operate as a self-directed team?
2. How will cell performance be measured and reported, and to whom?

Job Definitions and Assignments

1. Will new positions be required? Have they been defined?
2. Will cell operators be specialists or cross-trained to work anywhere in the cell?
3. Will operators rotate assignments on a regular basis?
4. How will the initial cell operators be recruited or assigned? Will the opportunity be posted plant-wide?
5. How will future operators be assigned?

Compensation & Incentives

1. Will operators be compensated on a different basis from other parts of the plant?
2. Will operators be paid for skills or cross training?
3. Will a group incentive be used? How will it be calculated?

Systematic Planning and Involvement

The planner can generally achieve a good result by planning each individual cell with the six-step procedure outlined in this Planning Guide. As each cell is planned, look first at the physical, then the procedural, and finally at the personal aspects of the project. At every step, be sure to involve prospective operating personnel and others from the relevant supporting groups. Working as a group to answer the questions above will assure that the final, selected plan will have a smooth implementation and deliver the benefits desired.

REFERENCES AND ADDITIONAL INFORMATION

If the project is large or complex, and involves multiple cells, the planner should apply our complete method: Systematic Planning of Manufacturing Cells (SPMC), as described in Reference 3 below and on our website at: www.hpcinc.com/rma.html

1. The Working Forms shown in Figures 2, 3, 7 and 9, plus more than a dozen additional forms for various aspects of cell planning are available at our website:
2. For more detail on the six-step procedure described in this guide, see the booklet:

Simplified Systematic Planning of Manufacturing Cells,

By Richard Muther, William E. Fillmore, and Charles P. Rome.

ISBN: 0933684-13-4.

Order from Management & Industrial Research Publications,

P.O. Box 7133, Kansas City, Missouri, USA 64113

Phone: 816-444-6622. Fax: 816-444-1140

Price (2002): \$12.00 (Included free with the SME Fundamentals of Manufacturing Cell Planning video and training package above).

3. For a complete guide to our popular method: Systematic Planning of Manufacturing Cells (SPMC), see the textbook:

Planning Manufacturing Cells,

By H. Lee Hales and Bruce Andersen,

Society of Manufacturing Engineers, Dearborn, Michigan, 2002.

ISBN: 0-87263-549-X

Price (2002): \$79/SME members \$67

Included free with Fundamentals of Cell Planning Video and Training Package.

Order from Society of Manufacturing Engineers,

P.O. Box 930, Dearborn, Michigan, USA 48121.

Phone: 800-733-4763 or 313-271-1500 (ext. 1600).

Order code: BK02PUB2-4695

On-line/e-mail: www.sme.org or: service@sme.org

4. For classroom case exercises and discussion problems, or to practice Systematic Planning of Manufacturing Cells (SPMC), see the workbook:

Planning Manufacturing Cells (Workbook)

By Richard Muther & Associates,

Society of Manufacturing Engineers, Dearborn, Michigan, 2002.

ISBN: 0-87263-550-3

Price (2002): \$20. One copy included with Fundamentals of Cell Planning Video & Training Package.

Order from Society of Manufacturing Engineers,

P.O. Box 930, Dearborn, Michigan, USA 48121.

Phone: 800-733-4763 or 313-271-1500 (ext. 1600).

Order code: BK02PUB3-4695

On-line/e-mail: www.sme.org or: service@sme.org

5. For self-instruction, classroom training, and orientation of cell-planning teams.

Fundamentals of Manufacturing Cell Planning (Three-tape Video and Training Package, includes live footage of installed cells, plus a step-by-step illustration of successful cell planning using Systematic Planning of Manufacturing Cells (SPMC). Training package includes: text, workbook, Simplified SPMC booklet on planning small cells, and pencil-ruler kit for process charting and cell flow diagramming)

By: H. Lee Hales, Bruce Andersen, and William E. Fillmore,
Society of Manufacturing Engineers, Dearborn, Michigan, 2002.

Price (2002): \$799/SME members \$715

Order from Society of Manufacturing Engineers,
P.O. Box 930, Dearborn, Michigan, USA 48121.

Phone: 800-733-4763 or 313-271-1500 (ext. 1600).

Order code: PK02PUB2-4695

On-line/e-mail: www.sme.org or: service@sme.org

6. For in-house training in cell planning, please visit our website. Course outlines of various lengths are available for review.

To learn more about our other planning methods, visit our website at:
www.hpcinc.com/rma.html, or contact us at:

Richard Muther & Associates
151 Village Parkway, Building 6
Marietta, Georgia, 30067 USA
Phone: 770-859-0161
Fax: 770-859-0166