PQM 201
CREATING MANUFACTURING PLANS
by J.M. Carter, PhD

Manufacturing involves the transformation of raw materials into useful finished goods. This transformation is accomplished through the utilization of company resources: labor, materials, facilities, and equipment. To assure that manufacturing is accomplished in an efficient manner, manufacturing plans must be established. These plans give detailed information on how the product will be made. It includes identification of purchased materials, equipment to be used, operations to be performed, flow of materials through the plant, labor requirements, etc.
Manufacturing planning begins well in advance of any actual production. In fact, a contractor should create preliminary plans as an input to their cost estimating for the bid process. The plans are continuously updated throughout production as efforts are undertaken to improve the process. The creation of a manufacturing plan requires a systematic process for answering questions such as the following:

- What is the product to be produced?
- What assemblies/parts/components compose the final product?
- Who will manufacture the components?
- What equipment/operations are required?
- Where will the components be made?
- What type of labor is involved?
- How long does it take to produce the components/assemblies?
- What raw materials are required?
- How much of each component/assembly must be produced?
- How should the product flow through the plant?
- What should the lot sizes be?

The first step in creating a manufacturing plan is to gain a thorough understanding of the item to be produced. This is accomplished by reviewing drawing and detailed design specifications. One of the most useful drawings is the exploded assembly drawing. Not only does this drawing give the planner a feel for the types of components and complexity of the product, but also allows the planner to visualize how the components must be assembled. If exploded assembly drawings are not available, the planner may rely on a prototype which can be disassembled.
A supplement to the exploded assembly drawing is the bill-of-materials. This gives the planner a structured list of all assemblies/parts/components that make up the final product. A sample bill-of-materials is given in Figure 1. This bill-of-materials is for an overhead projector which will be used as an example throughout this paper.

After reviewing the overall product through assembly drawings, prototypes, and bill-of-materials, the planner must obtain detailed drawings for each component and/or subassembly in the product. These will be required to determine detailed routings and operations needed to manufacture each component.

BILL-OF-MATERIALS

COMPANY: The MEAD Corp. PREPARED BY: Mickey Carter

PRODUCT: Overhead Projector DATE: 1 May 96

Level	Part No.	Part Name	Drwg. No.	Qty/Unit
0	0051	Overhead Projector	A051	1
1	1010	Lens Assembly	B101	1
1	1020	Adjustment Post	B102	1
1	1030	Base Assembly	B103	1
1	various	Assembly Hardware	A051	1
2	2010	Lens	B201	1
2	2011	Lens Housing	B201	1
2	2030	Base Shroud	B203	1
2	2031	Glass Cover	B203	1
2	2032	Electrical Subassembly	B204	1
2	various	Base Assembly Hardware	B203	1
3	various	Electrical Subcomponents	B204	1

Figure 1 Bill-of-Materials for Overhead Projector

Once the planner has a thorough understanding of the product, decisions must be made on which parts will be made in-house versus those that will be contracted to other organizations. These decisions are management decisions which require input from other organizations, such as: marketing, purchasing, finance, industrial engineering, process engineering, etc. This step requires answering questions such as:

- Do we have the capability to make this part?
- Do we have the capacity to make this part?
- What equipment is required?
- What labor skills are required?
- Is there an out-of-house source for this part?
- What is the economical impact?

Typically, if in-house capability exists, then the part should be made in-house. If in-house capability does not exist, then the part should be purchased. Many parts will carry a make or purchase designation because both contract and in-house capability exists. In these cases, the most economical alternative should be chosen. However, there are exceptions to these rules. Most exceptions deal with the ability of a vendor to meet required delivery dates. If a vendor cannot deliver in time to meet final product delivery, then the part may have to be made in-house even though this is not the most economical alternative.

Subsequent to the make/buy decisions, all parts and raw materials must be identified along with their make/buy designations. Raw materials would be identified for make parts only. This may be summarized in a parts list as shown in figure 2. In our example, the in-house manufacturing facility will produce all major plastic components, assemble all subassemblies as well as the final assembly, and purchase everything else.

Once make/buy decisions are determined, decisions must be made on "how to" manufacture all in-house components and assemblies. This step requires selecting the specific processes, equipment, and labor to be used for each part. For each part, a route sheet is developed. This document gives details of all steps required to manufacture the part. This requires intimate knowledge of the process and equipment capability within a plant. Because different plants have different equipment and labor skills, it is highly unlikely that the route sheets for the same product in two different plants would be identical. In fact, because process planners have different knowledge, it is not uncommon for two process planners within the same plant to create slightly different process plans for the same part.

PARTS LIST

COMPANY: The MEAD Corp. PREPARED BY: Mickey Carter

PRODUCT: Overhead Projector DATE: 1 May 96

Part No.	Part Name	Qty/Unit	Material	Make/Buy
0051	Overhead Projector	1	---	Make
1010	Lens Assembly	1	---	Make
1020	Adjustment Post	1	Steel	Buy
1030	Base Assembly	1	---	Make
various	Assembly Hardware	1	Steel	Buy
2010	Lens	1	Glass	Buy
2011	Lens Housing	1	Plastic	Make
2030	Base Shroud	1	Plastic	Make
2031	Glass Cover	1	Glass	Buy
2032	Electrical Subassembly	1	---	Make
various	Base Assembly Hardware	1	Steel	Buy
various	Electrical Subcomponents	1	---	Buy
	Packaging	1	Cardboard Polystyrene Plastic sheet	Buy
	ABS plastic granules (raw material for all plastic parts mfg. in-house)		Plastic	Buy

Figure 2 Parts List for Overhead Projector

Since differences in process plans is the norm instead of the exception, it is imperative that anyone responsible for production surveillance have access to the **actual process plans** in use. Determination of schedule slippage or part requirements based on hypothesized plans will **alway**s provide erroneous results.
A sample route sheet for one of the manufactured parts (e.g. the lens housing) in the overhead projector is provided in figure 3. As a minimum, a route sheet should provide the following:

- Component name/number
- Operation description
- Tooling requirements
- Process/Equipment/Labor requirements
- Set-up times
- Unit production times
- Raw material requirements

Although the route sheet gives detailed information on the manufacture of each part/component, it does not contain information on how to combine the components/subassemblies into the final product. This information is found on an assembly chart which is developed by the production planner. The assembly chart is constructed by exploding the final product into its elemental components found in the bill-of-materials or parts list. An example assembly chart can be seen in figure 4. In this chart a circle denotes an operation, whereas a square denotes an inspection.

ROUTE SHEET

Company: The MEAD Corp. **Part:** Lens housing **Prepared by:** M. Carter

Product: Overhead Projector **Part No:** 2010 **Date:** 1 May 96

Op Code	Operation Description	Mach/ Labor	Tooling	Dept.	Set-up Time	Oper. Time	Raw Materials
10	Injection mold top	Injection molder, #1471	molding dies, top set	Mold	1 hr	1.8 min	80 lbs ABS granules per 100 parts
20	Injection mold bottom plate	Injection molder, #1471	molding dies, bottom set	Mold	1 hr	1.8 min	50 lbs ABS granules per 100 parts
30	Flash trim top	Mold operator	trim knife	Mold	---	.5 min	
40	Flash trim bottom	"	"	Mold	---	.5 min	
50	Inspect top	"	caliper	Mold		.5 min	
60	Inspect bottom	"	"	Mold		.5 min	
70	Drill top holes	Drill press #1	0.25" dia. plastic drill bit drill jig	Mach	30 min	1.5 min	
80	Drill bottom holes	"	"	Mach	30 min	1.5 min	
90	Inspect top holes	Drill press operator	visual	Mach	---	.6 min	
100	Inspect bottom holes	"	visual	Mach	---	.6 min	

Figure 3 Route Sheet for Lens Housing Components

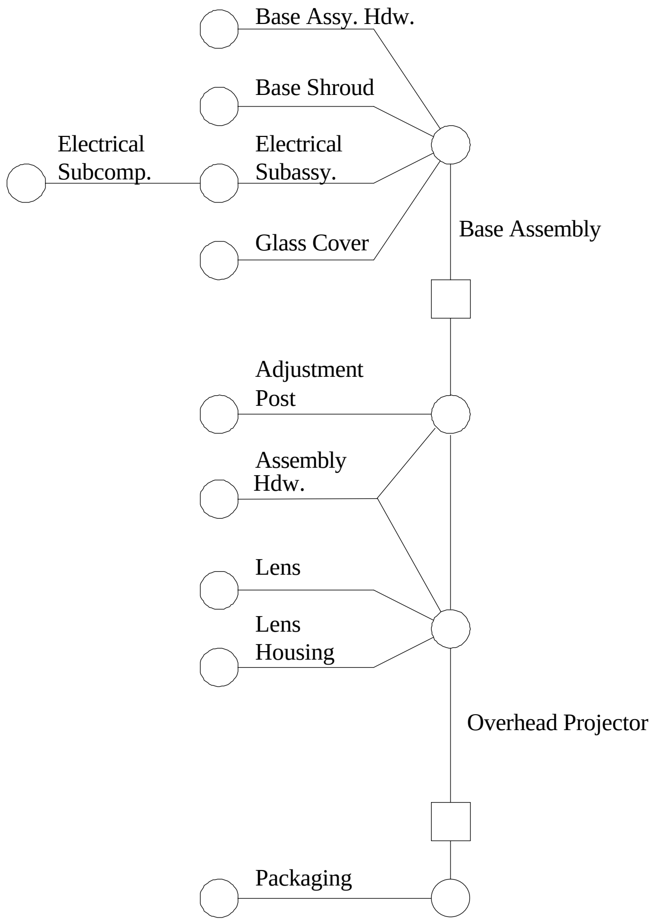

Figure 4 Assembly Chart for Overhead Projector

Assembly charts may be known by other names such as explosion diagrams, or *goesinto* chart.

The assembly charts and route sheets can be combined to provide an overall picture of the product flow within the plant. This chart is called an operation process chart. A sample operation process chart is depicted in figure 5. This chart is one of the most valuable charts used to describe the production process because it shows sequencing and precedence of all operations required to manufacture the product. Purchased parts can be easily identified by the fact that these parts do not contain any operations.

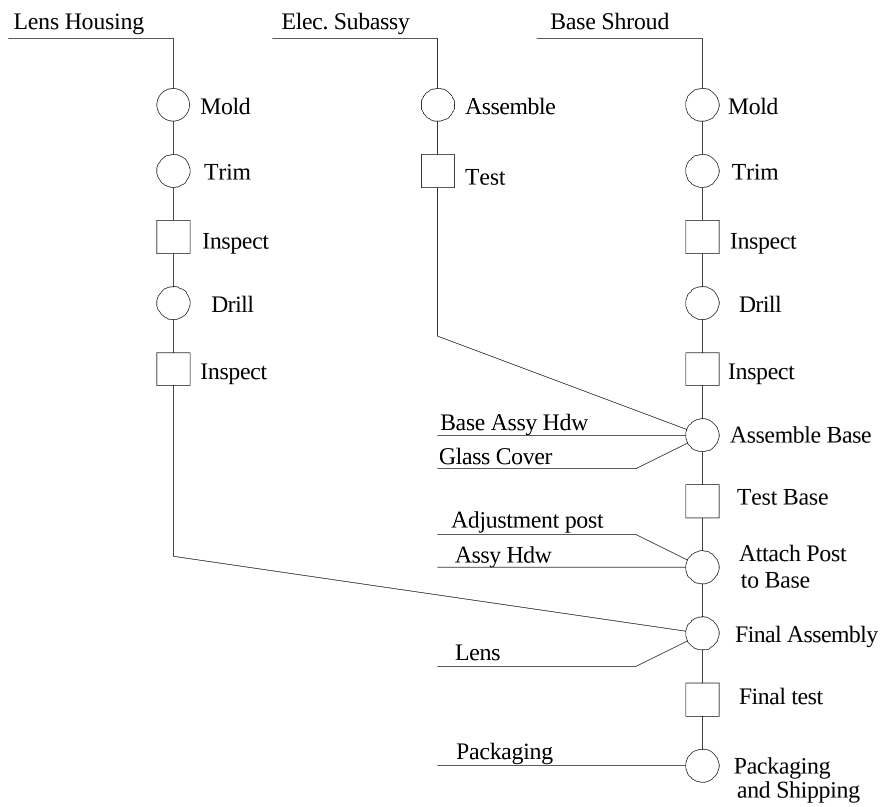

Figure 5 Operations Process Chart for Overhead Projector

A variation of the operation process chart is the precedence diagram or manufacturing plan. This chart is a network diagram similar to a PERT chart which adds schedule information to the operation process chart. This chart will be the input for monitoring production schedules by techniques such as Materials Resource Planning, Line of Balance, Milestone Charts, or Gantt Charts.

Construction of the manufacturing plan requires knowledge of the lot sizes released to production. Various techniques, such as economic order quantity or economic production quantity, are used to determine optimal lot sizes. Describing these techniques is beyond the scope of this paper; however, information on these techniques is readily available in any text on Operations Research, Production Control, or Inventory Management. For our example, let's assume that the economic lot size is 100.

With knowledge of lot sizes and the route sheets, we can determine times needed to complete a given operation. In figure 3, we see that two different departments are involved in manufacturing the lens housing. Molding of each piece takes 1.8 minutes. Flash trimming and inspection of each piece takes a total of 1 minute. Since an injection molding machine is basically automatic, the operator can be trimming and inspecting at the same time the machine is making the part.

Therefore, the part time for each piece is 1.8 minutes. Since each housing has both a top and bottom, the overall part time is 3.6 minutes. Therefore, to set up and produce 100 parts would require 8 hours (120 minutes setup and 360 minutes production).

Since drilling is accomplished on a drill press which would require operator control, the operator could not perform the inspection until after drilling was accomplished. Therefore, the part time for each piece is 2.1 minutes (1.5 min for drilling and 0.6 min for inspection). Since each housing has both a top and bottom, the overall part time is 4.2 minutes. Therefore, to set up and produce 100 parts would again require 8 hours (60 min setup and 420 min production).

For purchased parts and raw materials, the time from release of purchase order until receipt of parts must be determined. This information is obtained from purchasing or direct contact with the supplier. Some believe that procurement times should not be placed on the manufacturing plan. However, since the time to obtain procured parts and raw materials influences the ability to meet schedule, it is crucial that this information be indicated on the manufacturing plan. This helps to determine when suppliers are the cause of schedule slippage.

When these times are combined with the operation times for in-house manufactured parts, we can construct the overall manufacturing plan. A sample manufacturing plan is depicted in figure 6. In this manufacturing plan, the times reflect the time required to produce a single lot (i.e. 100 overhead projectors). This plan assists in assuring that work orders and purchase requests are released in sufficient time to support subsequent operations.

With this plan and the master schedule for the end product, we can accurately determine when to release work orders and purchase requests. This helps to assure that end products are delivered on schedule. Of course, problems can still occur which cause delays in executing the manufacturing plan.

After production has begun, various techniques such as line of balance, MRP, or milestone charting can be used to assess actual performance against the manufacturing plan. As stated before, the manufacturing plan is a required input to each of these techniques. But remember, the manufacturing plan used in applying these techniques must match the way the product is being produced.

References:

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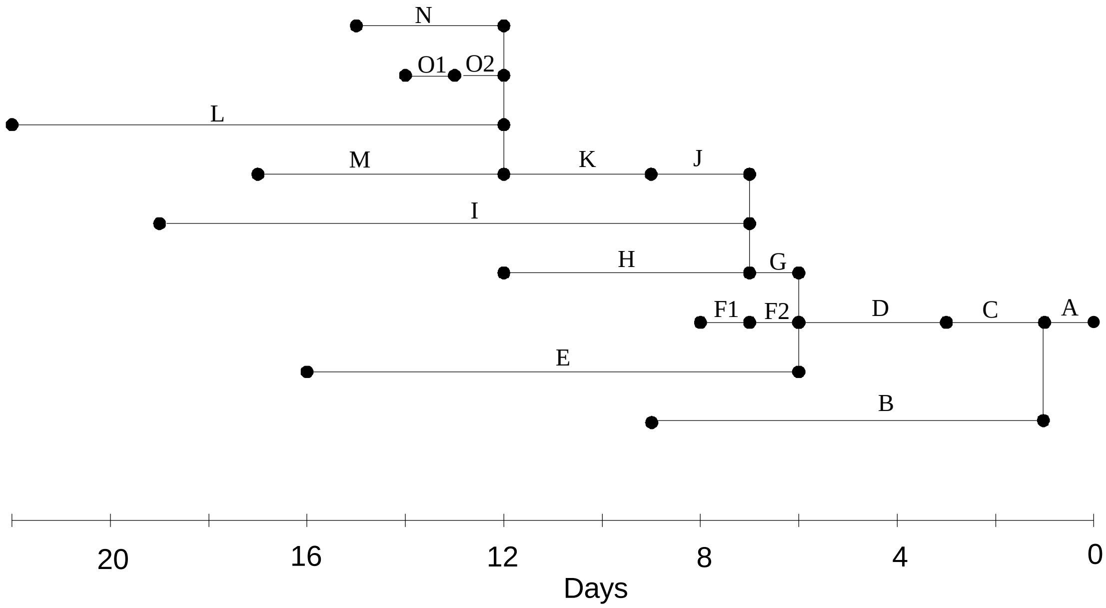

Operation	Description	Production Time
A	Pack and Ship	1 day
B	Procure Packaging Material	8 days
C	Final test	2 days
D	Final Assembly	3 days
E	Procure Lens	10 days
F2	Drill & Inspect Lens Housing	1 day
F1	Mold, Trim, and Insp Lens Housing	1 day
G	Attach Post to Base	1 day
H	Procure Assembly Hardware	5 days
I	Procure Adjustment Post	12 days
J	Test Base	2 days
K	Assemble Base	3 days
L	Procure Glass Cover	10 days
M	Procure Base Assy Hardware	5 days
N	Assemble & Test Elec. Subassy	3 days
O2	Drill & Inspect Base Shroud	1 day
O1	Mold, Trim, and Insp. Base Shroud	1 day

Figure 6 Manufacturing Plan for Overhead Projector