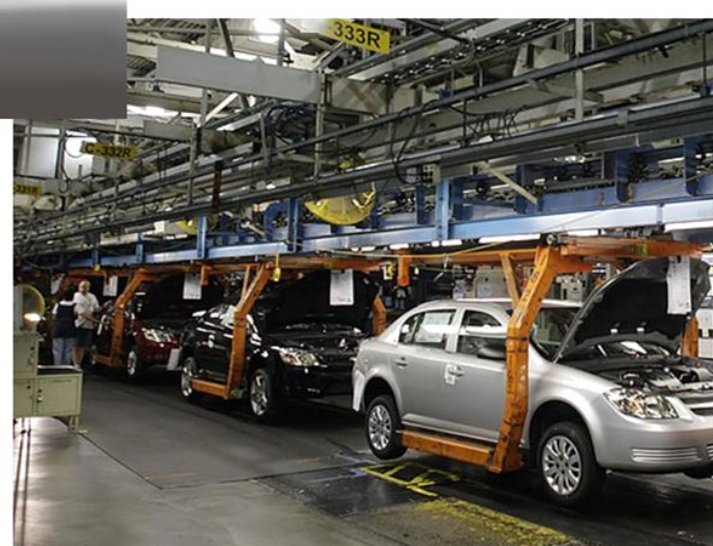


Product, Process and Schedule Design

Among the questions to be answered before alternative facility plans can be generated are the following:

1. What is to be produced?
2. How are the products to be produced?
3. When are the products to be produced?
4. How much of each product will be produced?
5. For how long will the products be produced?
6. Where are the products to be produced?

Product, process, and schedule design

Facilities location / schedule design

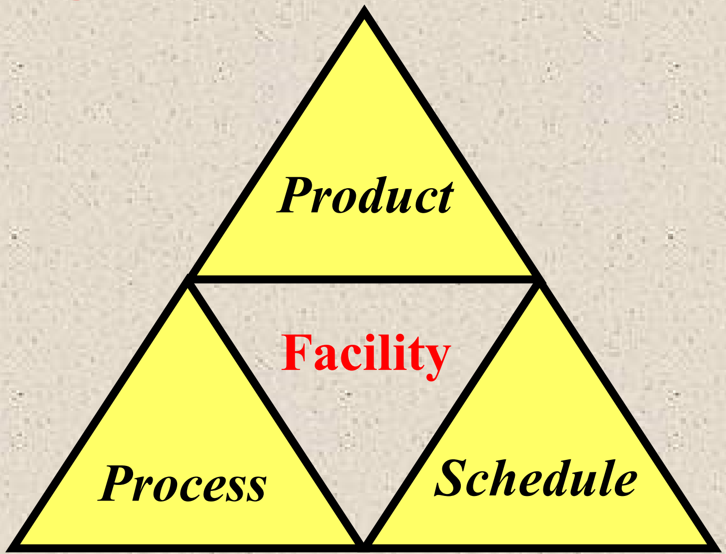
Input Data and Activities

- Tompkins, White, et. al., categorize it as:

Product Design – what is to be produced?

Process Design – how is it to be produced?

Schedule Design – when and how much?



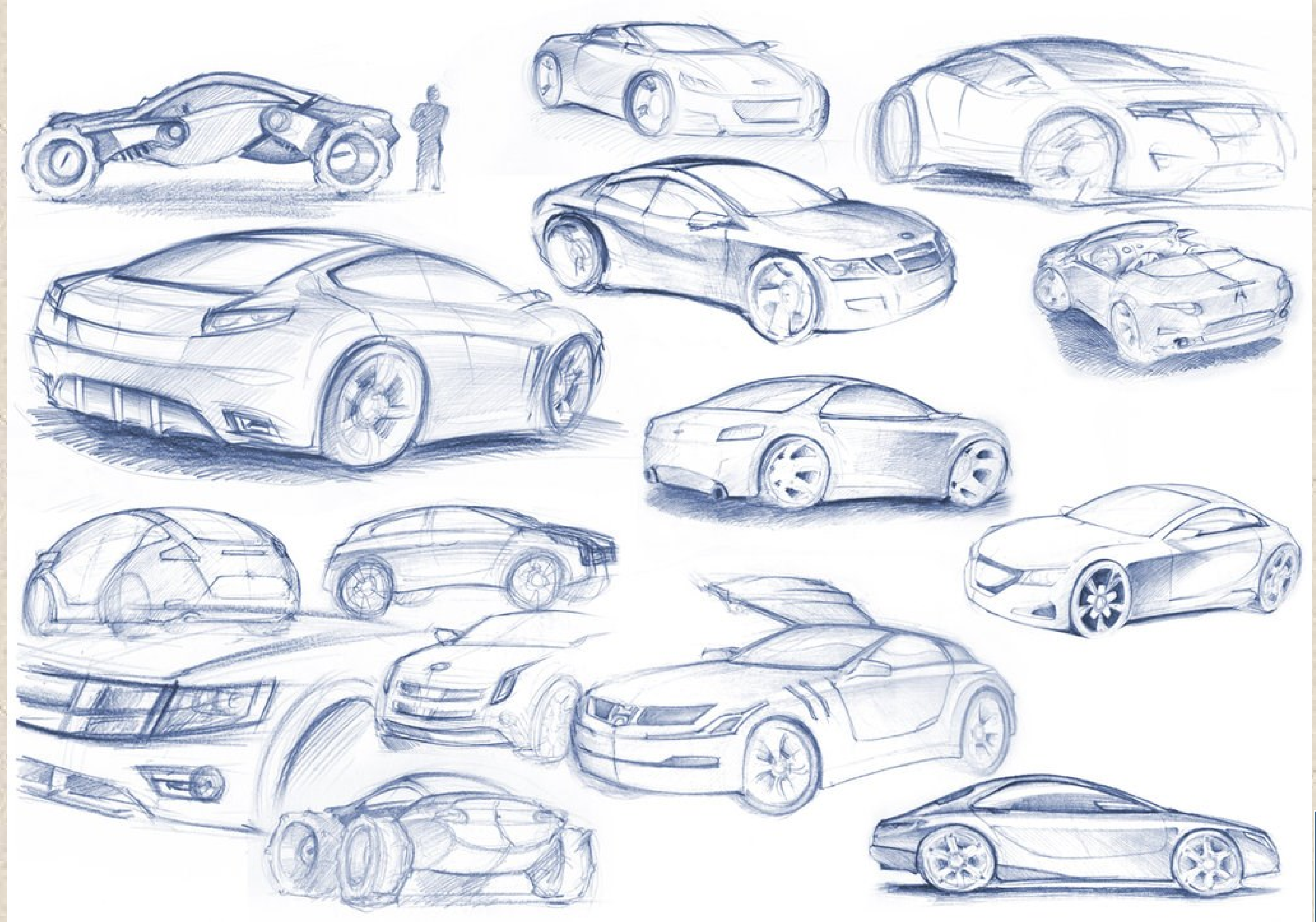
- **Product designers**
  - Types of products and specifications (dimensions)
  - Detail of components, material composition
  - Packaging
- **Process planner**
  - Required processes identification
  - Required processes sequence
- **Schedule designers / production planner**
  - Production quantities
  - Production equipment schedules

- **FACILITIES PLANNER**

  Is dependent on timely and accurate input from product, process, and schedule designers to work effectively

PRODUCT DESIGN

“What kind of product should be made?”



Product Analysis

Specification	☛	a. Dimension, Weight, Material & Drawing b. Quality of product c. Specific requirement
Volume	☛	Production quantity & variation
Part's Breakdown	☛	a. Flow process. b. Assembly process. c. Processing time. d. Machine, jig, tool and other.

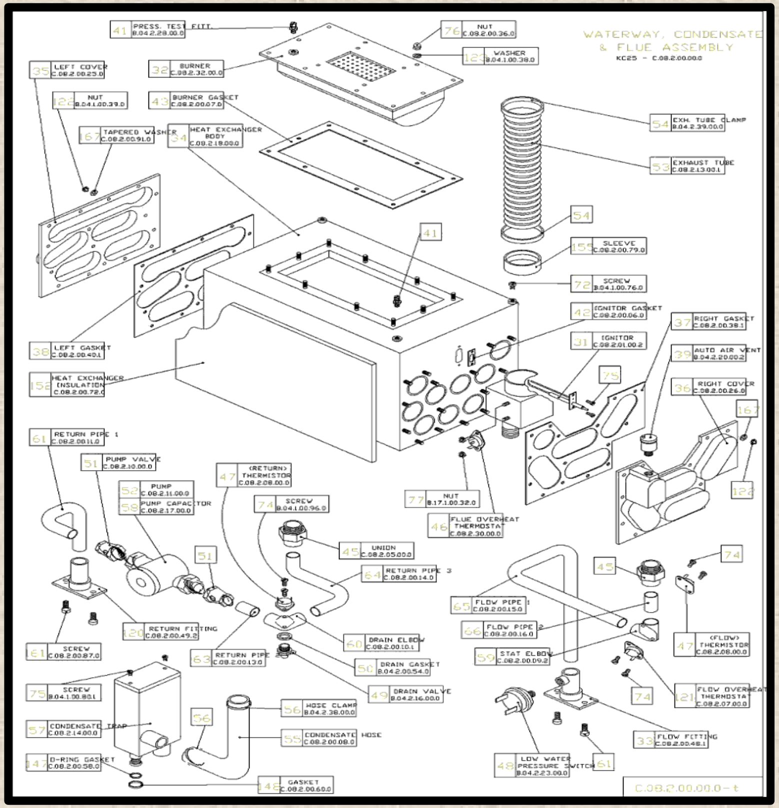
Product Design

- Based on
  - Function
  - Aesthetics
  - Costs
  - Materials
  - Manufacturing Methods
- **QFD**
- Benchmarking

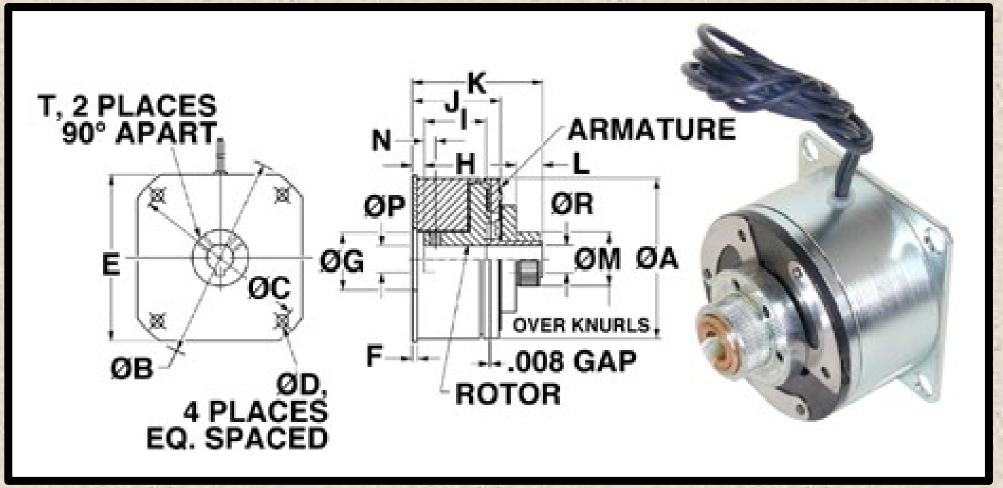
Driven by market demand

- Key point
  - The product design MUST be finalized before designing the facility. Otherwise a flexible facility is needed.

Tools Used in Product Design



- Product/Part Drawings
  - ➢ 2-D, 3-D visualization



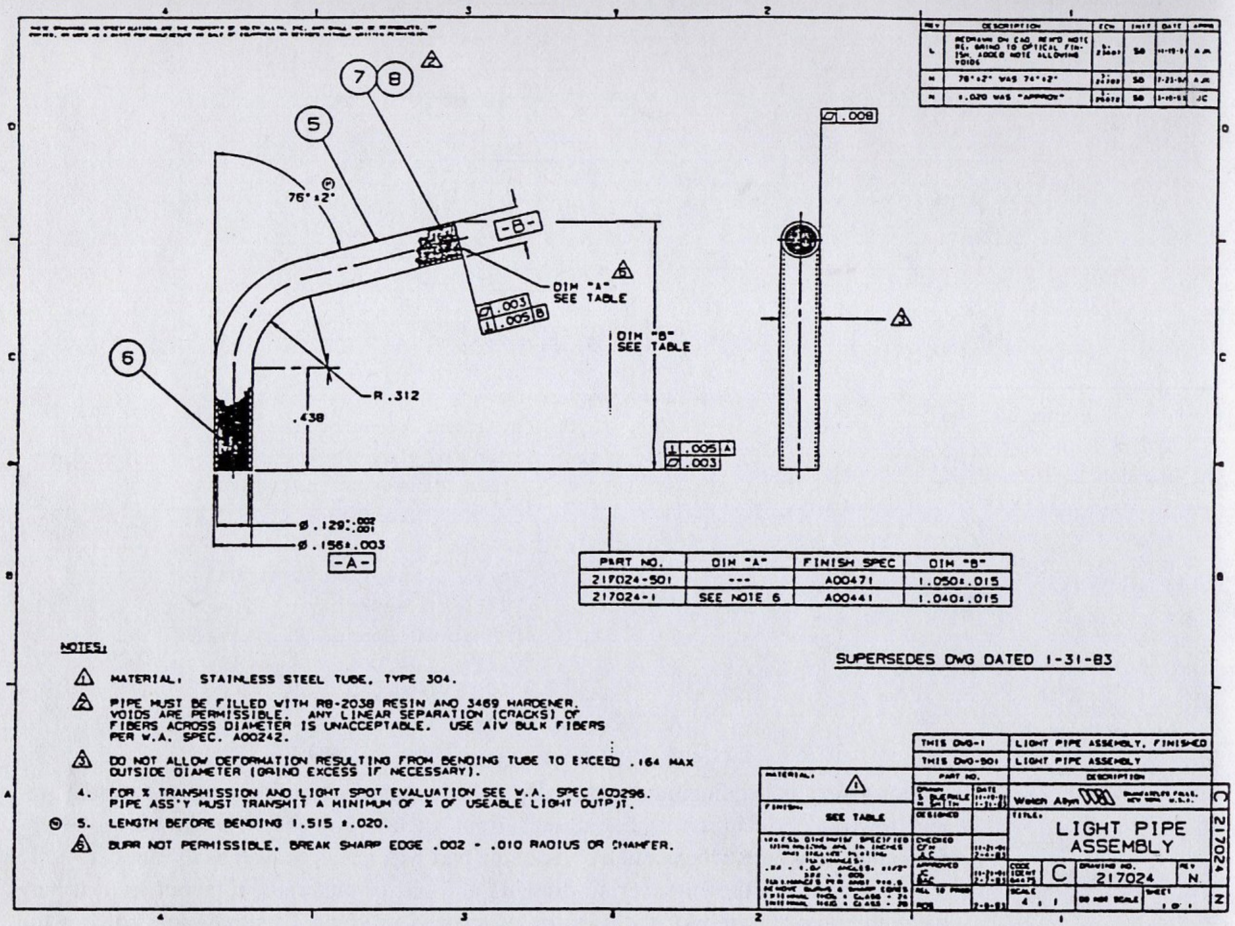
- Exploded Assembly Diagrams

Tools:

- CAD (*computer aided design*)
- CE (*concurent engineering*), to improve relationship between component/product and its cost

Part drawing

Figure 2.12 *Part drawing*



Source: Courtesy of Welch Allyn Medical Division

PROCESS DESIGN

Process Planner

- Responsibilities:
  - HOW the product is to be produced
  - WHO should do the processing
  - HOW the part will be produced
  - WHICH equipment will be used
  - HOW LONG it will take to perform the operation

Tools Used in Process Design

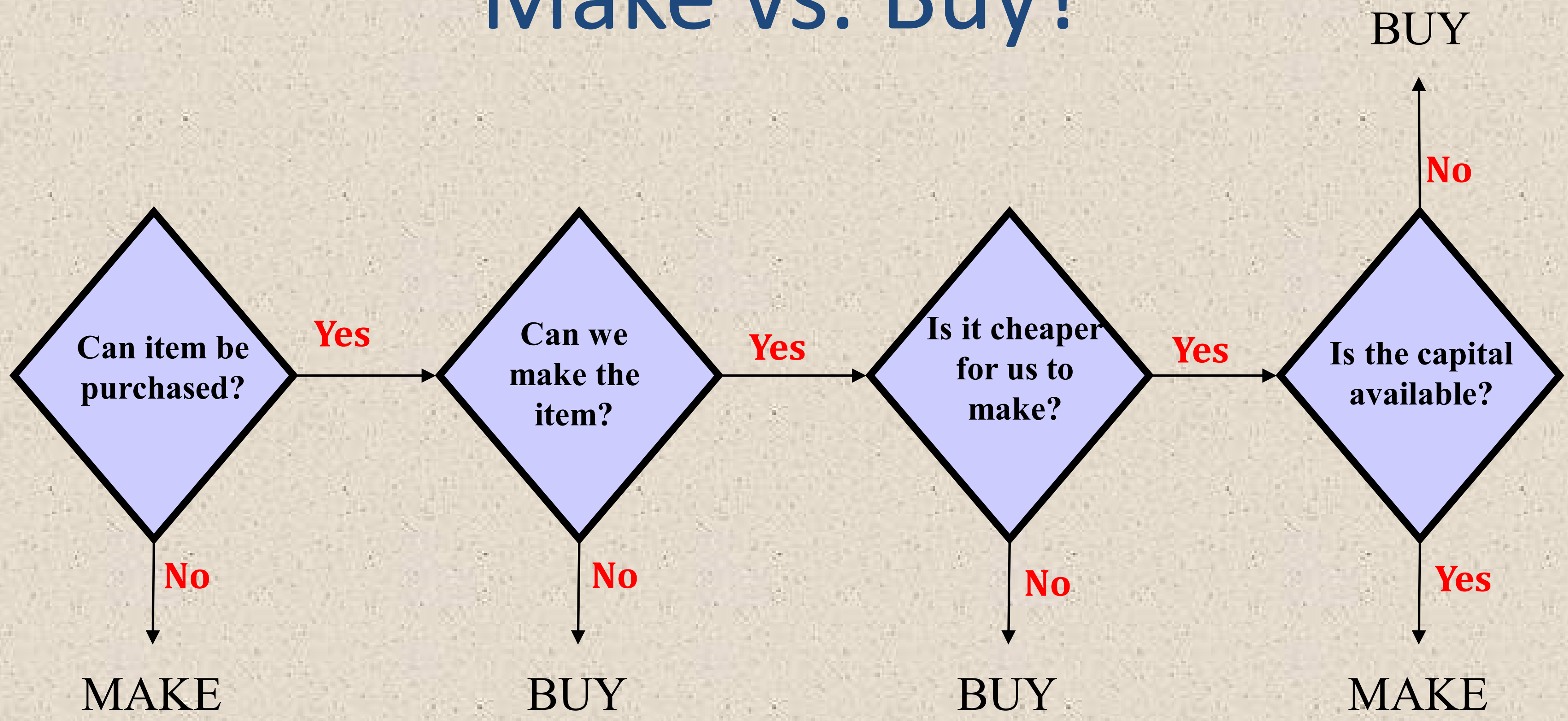
- **Identifying Required Processes:**
  - Make vs. Buy
  - Parts Lists
  - Bill of Materials

- **Selecting the Required Processes:**
  - Input: process identification

Process Identification	
Define elemental operations	Step 1
Identify alternative process for each operation	Step 2
Analyze alternative processes	Step 3
Standardize processes	Step 4
Evaluate alternative processes	Step 5
Select processes	Step 6

  - Tool: CAPP (*computer aided process planning*)
  - Output: Route Sheets

Make vs. Buy?


BUY
No
Can item be purchased?
Yes
Can we make the item?
Yes
Is it cheaper for us to make?
Yes
Is the capital available?
No
No
No
Yes
MAKE
BUY
BUY
MAKE

Parts List

- A listing of component parts.

PARTS LIST

Company: TW Inc. **Prepared By:** JSU
Product: Air Flow Regulator **Date:** 6/30/2003

Part No.	Name	Drwg. No.	Qty/unit	Material	Size	Make/Buy
1050	Pipe plug	4006	1	Steel	0.5" x 1.00"	Buy
2200	Body	1003	1	Aluminum	2.75" x 2.5" x 1.5"	Make
3250	Seat Ring	1005	1	Stainless Steel	2.97" x 0.87"	Make
3251	O-Ring	-	1	Rubber	0.75" diam.	Buy
3252	Plunger	1007	1	Brass	0.812" x 0.715"	Make
3253	Spring	-	1	Steel	1.4" x 0.225"	Buy
3254	Plunger Housing	1009	1	Aluminum	1.6" x 0.225"	Make
3255	O-Ring	-	1	Rubber	0.925" diam.	Buy
4150	Plunger Retainer	1011	1	Aluminum	0.42" x 1.2"	Make
4250	Lock Nut	4007	1	Aluminum	0.21" x 1.00"	Buy

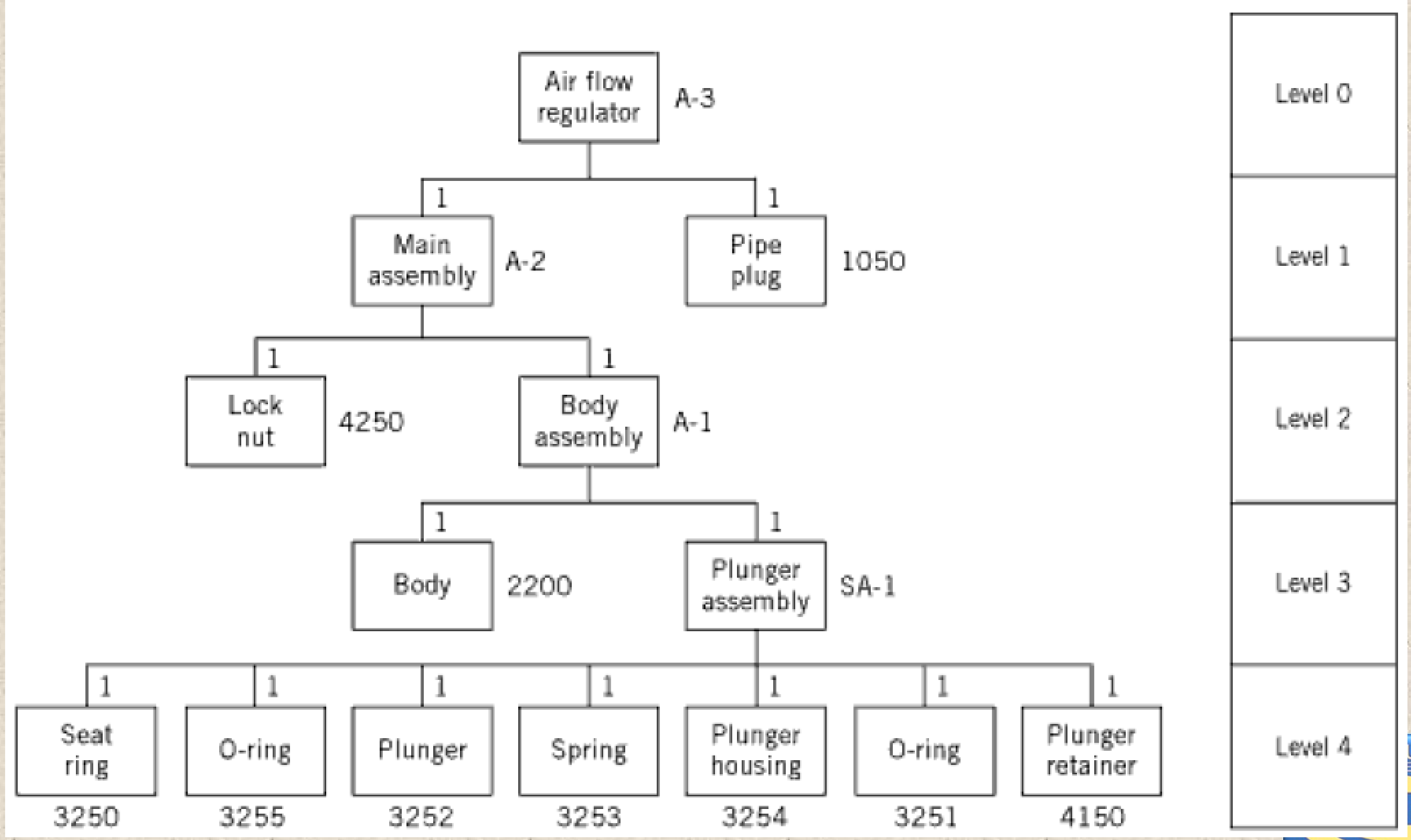
Bill of Materials

BILL OF MATERIALS

Company T.W., Inc. Prepared by J.A.
Product Air Flow Regulator Date

Level	Part No.	Part Name	Drwg. No.	Quant./ Unit	Make or Buy	Comments
0	0021	Air flow regulator	0999	1	Make	
1	1050	Pipe plug	4006	1	Buy	
1	6023	Main assembly	—	1	Make	
2	4250	Lock nut	4007	1	Buy	
2	6022	Body assembly	—	1	Make	
3	2200	Body	1003	1	Make	
3	6021	Plunger assembly	—	1	Make	
4	3250	Seat ring	1005	1	Make	
4	3251	O-ring	—	1	Buy	
4	3252	Plunger	1007	1	Make	
4	3253	Spring	—	1	Buy	
4	3254	Plunger housing	1009	1	Make	
4	3255	O-ring	—	1	Buy	
4	4150	Plunger retainer	1011	1	Make	

Bill of Materials



Route Sheet

Company: ARC Inc. Part: Plunger Housing Prepared by: JSU

Produce: Air Flow Regulator Part No. 3254 Part No. 6/6/03

Oper. No.	Operation Description	Machine Type	Tooling	Setup (hr.)	Oper. Time (hr.)	Mtls. Parts
0104	Shape, drill, cut off	Auto sc. Machine	.5 in dia coller, cir. Form tool, .45” diam center drill	5	0.0057	Alum 1”x12’
0204	Machine Slot and thread	Chucker	0.045” slot saw, turret slot	2.25	0.0067	
0304	Drill 8 holes	Auto dr. unit	0.078” diam twist drill	1.25	0.0038	
0404	Debur and Blow out	Drill press	Deburring tool with pilot	0.5	0.0031	
SA 1	Enclose subassembly	Dennison hydraulic press	None	0.25	0.0100	

Routing sheet

```
                                                             MASTER ROUTING LIST
--PART NUMBER--  ---------DESCRIPTION----------     DATE     ALT CODE       BUYER/PLANNER
DRAWING REVISION
H6709            HANDLE,DENSPLY PROBE              6/25/92       B               239
 G
                                                             --------STANDARD--------
TIME      MOVE
OPER   WORK  OPER  SETUP   CREW   MACH  --TOOLING REF--  --SETUP-   -LABOR-   -MACHINE--  I/O
BASIS     TIME    -----EFFECTIVE----
& ALT CENTER CODE  CODE  FACTOR  GROUP      NUMBER          HOURS     HOURS      HOURS
CDE/-QTY-   -DAYS-    FROM       TO
  10   01226               1.0  01226  T9330              12.000   336.880    336.880        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            MAKE @ AUTO 804843P
            C 804843P B
            A A02247 A
  15   02053               1.0  02053  T9712               1.500    41.670     83.330        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            DRILL & TAP 804843P1
            B 804843P1 A
  20   02053               1.0  02053  T9713               1.500     8.330     16.670        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            KNURL OD
  30   03029               1.0                              .000    33.330     33.330        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            SCOTCHBRITE/BELT
  40   03105               1.0  03105                       .000     3.000      3.000        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            PASSIVATE
  50   03005               1.0                              .000    54.170     54.170        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            BUFF
  60   03007               1.0  03007                       .000    50.000     50.000        4
1000     .000   0/00/00  99/99/99
PARTIAL AHEAD QTY
            ----------ROUTING DESCRIPTIONS----------
            GLASSBEAD KNURL/  SHIP
```

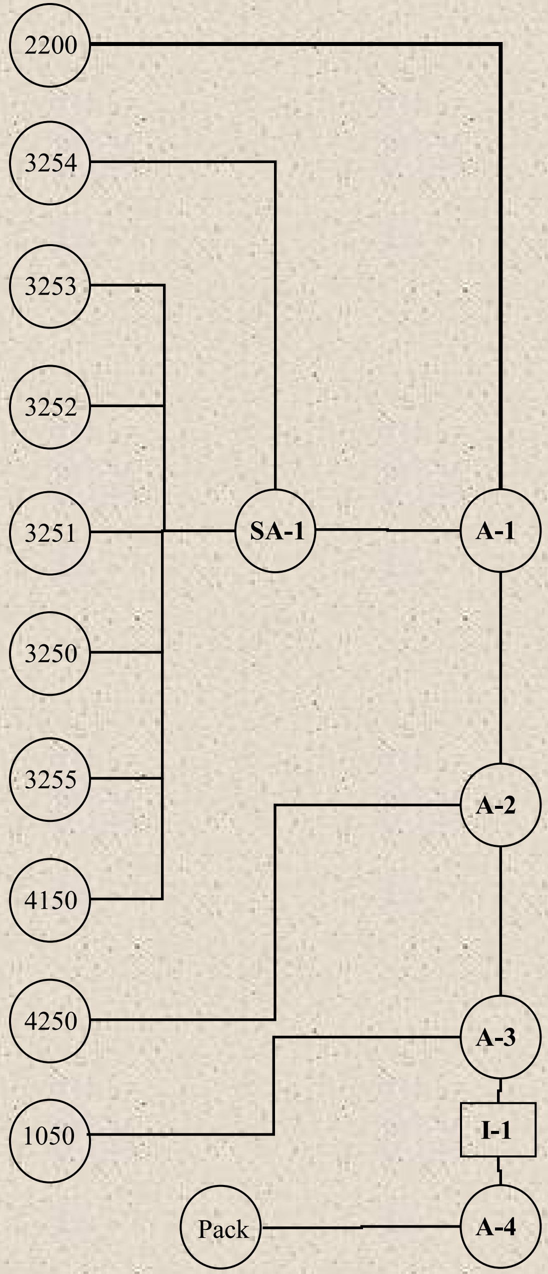
Tools Used in Process Design

- **Sequencing the Required Processes:**
  - Assembly Charts
  - Operations Process Charts
  - Process Flowcharts and Process Maps
  - Precedence Diagrams

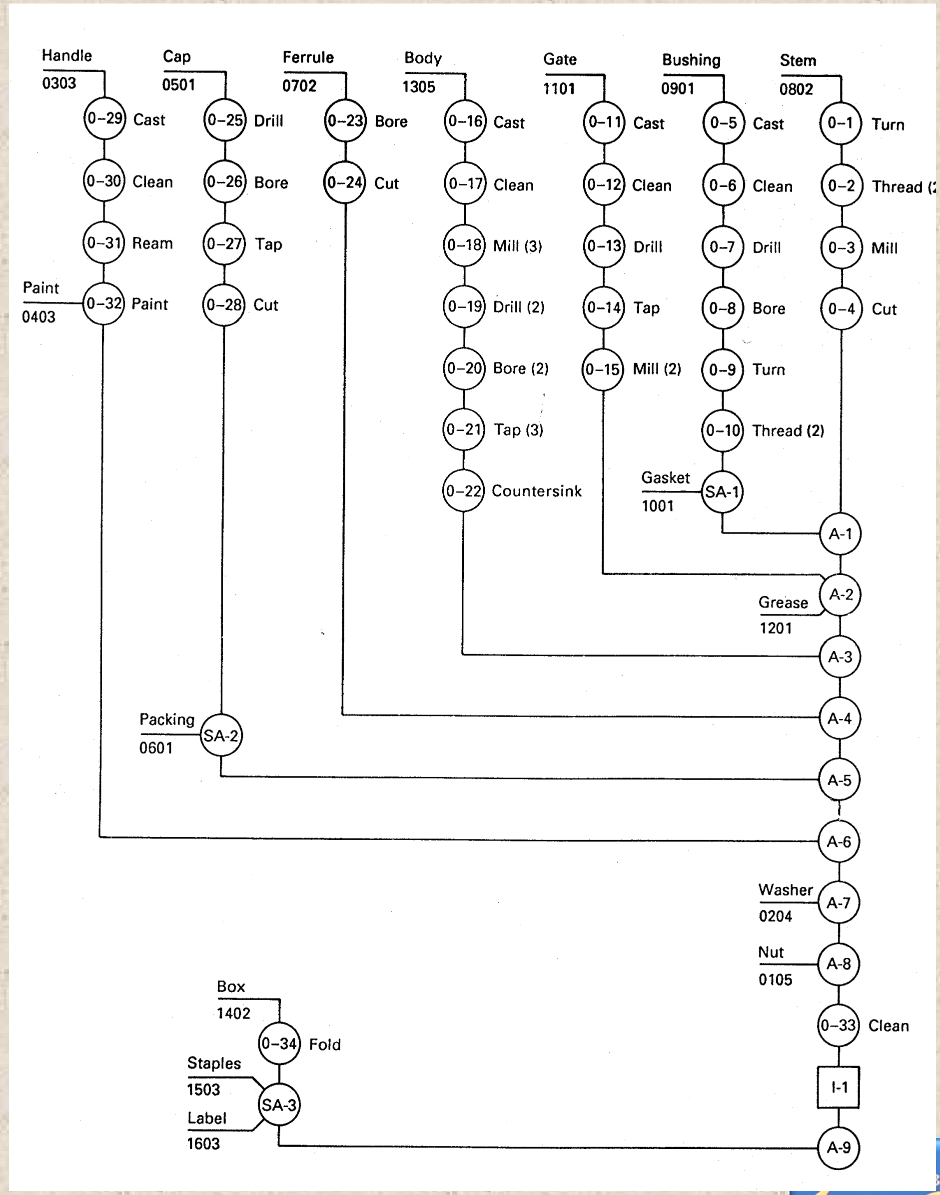
Assembly Chart

Analog model of the assembly process.

- Circles denote components
- Links denote operations/subassemblies
- Squares represent inspections operation
- Begin with the original product and to trace the product disassembly back to its basic components.

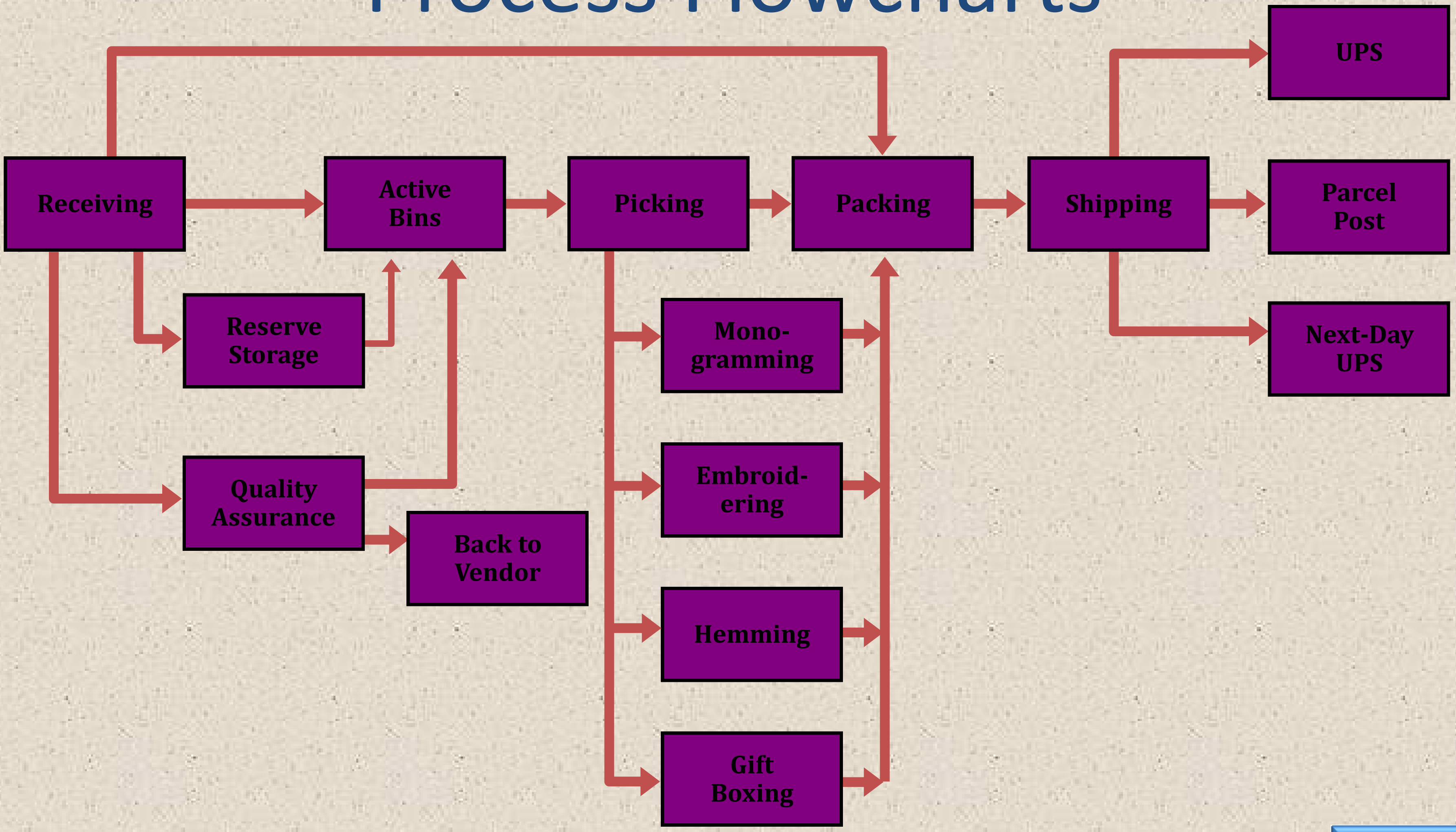


Found by superimposing the route sheets and the assembly chart, a chart results that gives an overview of the flow within the facility.

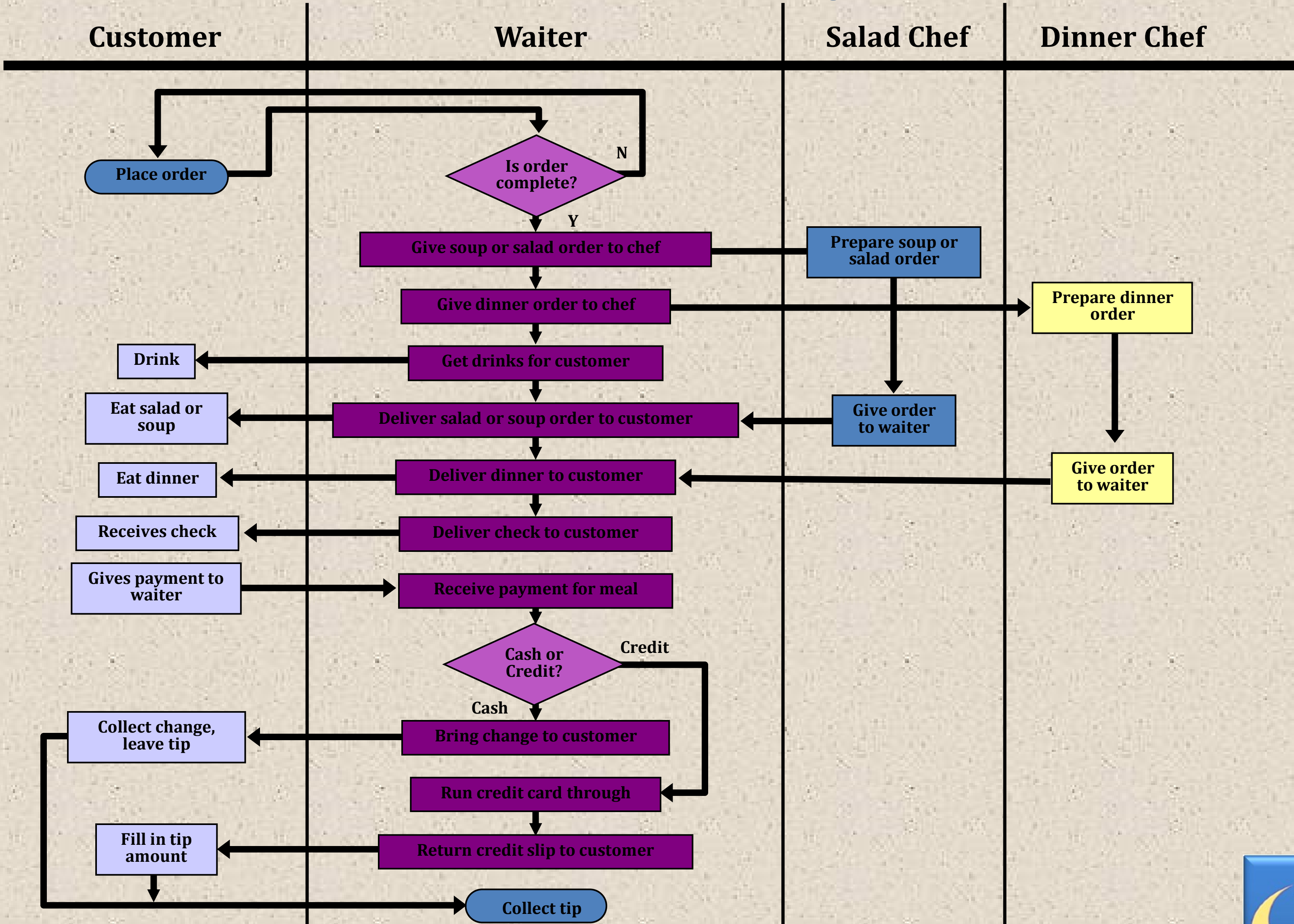


Operations Process Chart

Process Flowcharts



Process Maps



SCHEDULE DESIGN

http://www.observer.co.za/article/overall-outlook-motor-industry-remains-positive

Schedule Design

Answering questions:

- HOW MUCH to produce => lot size
- WHEN to produce => production scheduling

Depend on:

- How long production will continue

Impacts:

Machine selections, #machines, #shitfs, #employees, space requirements, storage equipment, MH equipment, personnel requirements, storage policies, unit load design, building size, etc.

Marketing Information

- Minimum market information required for Facilities Planning:

Product or Service	First Year Volume	Second Year Volume	Fifth Year Volume	Tenth Year Volume
A	5000	5000	8000	10,000
B	8000	7500	3000	0
C	3500	3500	3500	4000
D	0	2000	3000	8000

Marketing Information

- Valuable information that should be obtained from marketing and used by a Facilities Planner:

Information to Be Obtained from Marketing	Facilities Planning Issues Impacted by the Information
Who are the consumers of the product?	1. Packaging 2. Susceptibility to product changes 3. Susceptibility to changes in marketing strategies
Where are the consumers located?	1. Facilities location 2. Method of shipping 3. Warehousing systems design
Why will the consumer purchase the product?	1. Seasonability 2. Variability in sales 3. Packaging
Where will the consumer purchase the product?	1. Unit load sizes 2. Order processing 3. Packaging
What percentage of the market does the product attract and who is the competition	1. Future trends 2. Growth potential 3. Need for flexibility
What is the trend in product changes?	1. Space allocations 2. Materials handling methods 3. Need for flexibility

Process Requirements

- Schedule design determines the number of each equipment type required to meet the production schedule.

- Specification of process requirements typically occurs in three phases:
    1. Determines the quantity of components that must be produced, including scrap allowances, in order to meet market estimate
    2. Determines the equipment requirements for each operation
    3. Combines the operation requirements to obtain overall equipment requirements

Process Requirements

- SCRAP ESTIMATES

$$\boldsymbol{Number\ of\ units\ production} \\ \boldsymbol{=\ market\ estimate\ +\ scrap\ estimate}$$

  – Scrap: the material waste generated in the manufaturing process due to geometric or quality considerations

Process Requirements

- SCRAP ESTIMATES

Let;
P_k = percentage of scrap produced on the k^{th} operation,
O_k = the desired output of nondefective product from operation k,
I_k = the production input to operation k.

$$O_k = I_k - P_k I_k \qquad \text{or} \qquad O_k = I_k(1 - P_k)$$

Hence;

$$I_k = \frac{O_k}{1 - P_k}$$

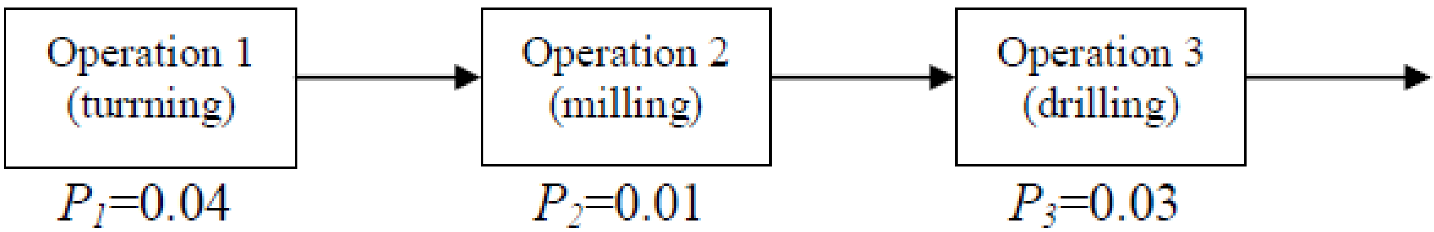
Thus, the expected number of units to start into production for a part having n operations is

$$I_k = \frac{O_n}{(1 - P_1)(1 - P_2)\dots(1 - P_n)}$$

where in this case O_n is the market estimate.

Example:

A product has a market estimate of 97,000 components and requires three processing steps (turning, milling, and drilling) having scrap estimates of $P_1=0.04$, $P_2=0.01$, $P_3=0.03$. Calculate the production input to operation 1.



$$I_3 = \frac{97{,}000}{1-0.03} = 100{,}000 \qquad \left(I_k = \frac{O_k}{1-P_k} \right)$$

$$I_2 = \frac{100{,}000}{1-0.01} = 101{,}010$$

$$I_1 = \frac{101{,}010}{1-0.04} = 105{,}219 \qquad \left(\text{or; } I_1 = \frac{97{,}000}{(1-0.04)(1-0.01)(1-0.03)} = 105{,}219 \right)$$

Summary of Production Requirements		
Operation	Production Quantity Scheduled (units)	Expected number of good units produced
Turning	105,219	101,010
Milling	101,010	100,000
Drilling	100,000	97,000

Table 4.5. Summary of production requirements

Process Requirements – Non Series

Work backward from end of the line.

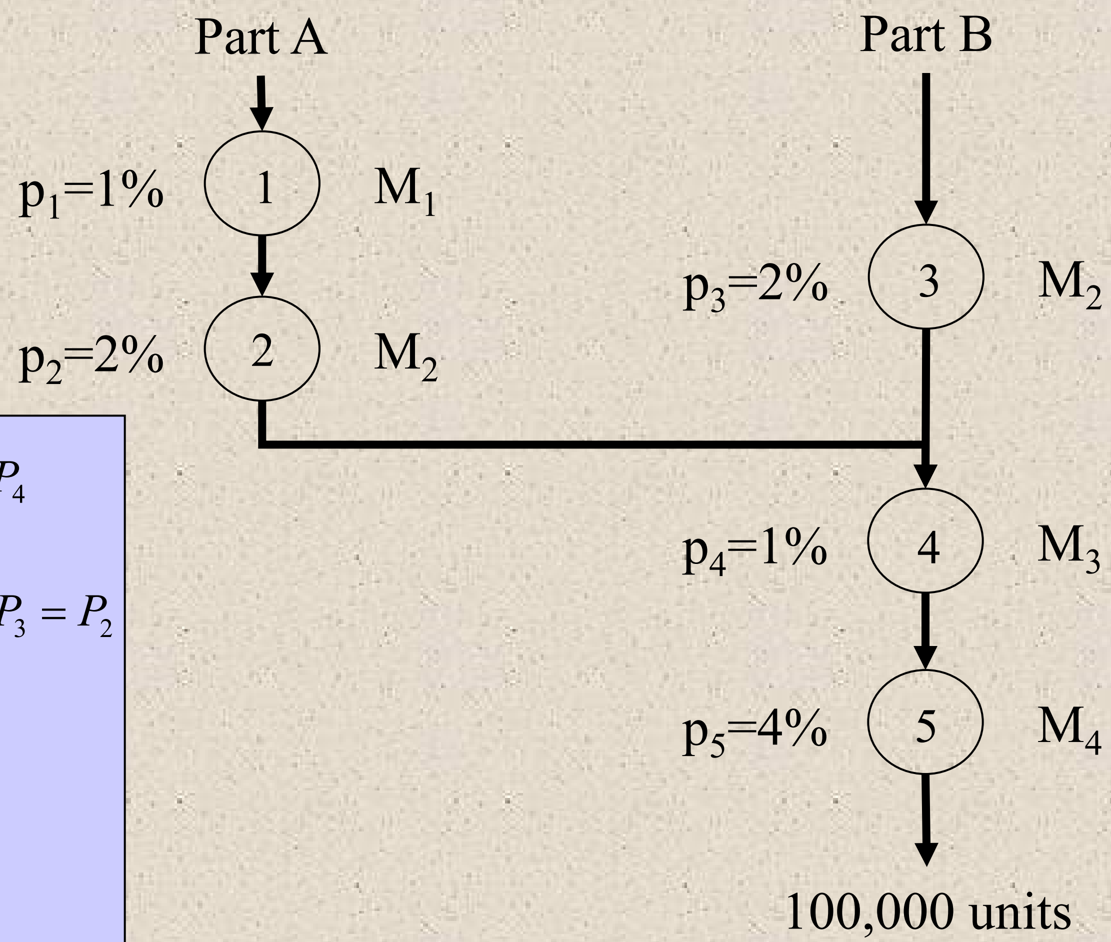
$$S_5 = \frac{P_5}{1-p_5} = \frac{100{,}000}{.96} = 104{,}167 = P_4$$

$$S_4 = \frac{P_4}{1-p_4} = \frac{104{,}167}{.99} = 105{,}219 = P_3 = P_2$$

$$S_3 = \frac{P_3}{1-p_3} = \frac{105{,}219}{.98} = 107{,}366$$

$$S_2 = \frac{P_2}{1-p_2} = \frac{105{,}219}{.98} = 107{,}366$$

$$S_1 = \frac{P_1}{1-p_1} = \frac{107{,}366}{.99} = 108{,}451$$



Process Requirements

- EQUIPMENT FRACTIONS
  - The quantity of equipment required for an operation
  - Total time required to perform the operation divided by the time available to complete the operation

$$F = \frac{SQ}{EHR}$$

where; F = number of machines required per shift
S = standard time (minutes) per unit produced
Q = number of units to be produced per shift
E = actual performance, expressed as a percentage of standard time
H = amount of time (minutes) available per machine
R = reliability of machine, expressed as percent "up time"

Process Requirements

- EQUIPMENT FRACTIONS

Equipment requirements are a function of the following factors:

- Number of shifts (the same machine can work in more than one shift).
- Setup times (if machines are not dedicated, the longer the setup, the more machines needed).
- Degree of flexibility (customers may require small lot sizes of different products delivered frequently – extra machine capacity will be required to handle these requests).
- Layout type (dedicating manufacturing cells or focused factories to the production of product families may require more machines).
- Total productive maintenance (will increase machine up time and improve quality, thus fewer machines will be needed).

Example:

A machine part has a machinery time of 2.8 min per part on a milling machine. During an 8-hr shift 200 units are to be produced. Of the 480 min available for production, the milling machine will be operational 80% of the time. During the time the machine is operational, parts are produced at a rate equal to 95% of the standard rate. How many milling machines are required?

$S = 2.8$ min per part,
$Q = 200$ units per shift,
$E = 0.95$,
$H = 480$ min per shift,
$R = 0.80$.

$$F = \frac{SQ}{EHR} = \frac{2.8 \times 200}{0.95 \times 490 \times 0.80} = 1.535 \text{ machines per shift}$$

Efisiensi Proses (E)

$$E = \frac{H}{D} = (1 - \frac{D_T + S_T}{D})$$

H : Running time per periode

D : Lama waktu kerja per periode (8 jam/hari untuk satu shift kerja)

D_T : Down Time

S_T : Set up Time per periode

Process Requirements

- MACHINE ASSIGNMENT PROBLEM
  - Operator-Machine Charts
    - Tool for showing activity of both operator and machine along a time line
    - Also called “multiple activity chart”
    - **Example:**
      - 1 minute to load
      - 1 minute to unload
      - 6 minute run cycle
      - 0.5 minute to inspect and pack
      - 0.5 minute to travel to another machine

ONE MACHINE

Time	Operator	M1
0.5	U1	UNLOAD
1	U1	UNLOAD
1.5	L1	LOAD
2	L1	LOAD
2.5	I&P	RUN
3		RUN
3.5		RUN
4		RUN
4.5		RUN
5		RUN
5.5	IDLE	RUN
6		RUN
6.5		RUN
7		RUN
7.5		RUN
8		RUN

Cycle Time	8	min
Oper Idle	5.5	min
Mach. Idle	0	min
Prod. Rate	0.125	pc/min

– Operator Machine Charts

TWO MACHINES

Time	Operator	M1	M2
0.5	U1	UNLOAD	RUN
1	U1	UNLOAD	RUN
1.5	L1	LOAD	RUN
2	L1	LOAD	RUN
2.5	I&P	RUN	RUN
3	T-2	RUN	RUN
3.5	U2	RUN	UNLOAD
4	U2	RUN	UNLOAD
4.5	L2	RUN	LOAD
5	L2	RUN	LOAD
5.5	I&P	RUN	RUN
6	T-1	RUN	RUN
6.5	IDLE	RUN	RUN
7		RUN	RUN
7.5		RUN	RUN
8		RUN	RUN

Cycle Time	8	min
Oper. Idle	2	min
Mach Idle	0	min
Prod Rate	0.25	pc/min

THREE MACHINES

Time	Operator	M1	M2	M2
0.5	U1	UNLOAD	RUN	RUN
1	U1	UNLOAD	RUN	RUN
1.5	L1	LOAD	RUN	RUN
2	L1	LOAD	RUN	RUN
2.5	I&P 1	RUN	IDLE	RUN
3	T-2	RUN	IDLE	RUN
3.5	U2	RUN	UNLOAD	RUN
4	U2	RUN	UNLOAD	RUN
4.5	L2	RUN	LOAD	RUN
5	L2	RUN	LOAD	RUN
5.5	I&P 2	RUN	RUN	IDLE
6	T-3	RUN	RUN	IDLE
6.5	U3	RUN	RUN	UNLOAD
7	U3	RUN	RUN	UNLOAD
7.5	L3	RUN	RUN	LOAD
8	L3	RUN	RUN	LOAD
8.5	I&P 3	IDLE	RUN	RUN
9	T-3	IDLE	RUN	RUN

Cycle Time	9	min
Oper. Idle	0	min
Mach Idle	1	min
Prod Rate	0.333333	pc/min

FACILITIES DESIGN

http://clinpharmnetwork.com/pages/consulting-services/facilities-design.php

Facilities Design

- Facilities planner :
  - Organize:
    - the information (product, process, and schedule design)
  - Generate and evaluate:
    - Layout design alternatives
    - Handling design alternatives
    - Storage design alternatives
    - Unit layout design alternatives

Facilities Design

- Tools:
  - Pareto Chart
  - Seven management and planning tools
    - Affinity diagram
    - Interrelationship diagraph
    - Tree diagram
    - Matrix diagram
    - Contigency diagram
    - Activity network diagram
    - Prioritization matrix

Affinity diagram

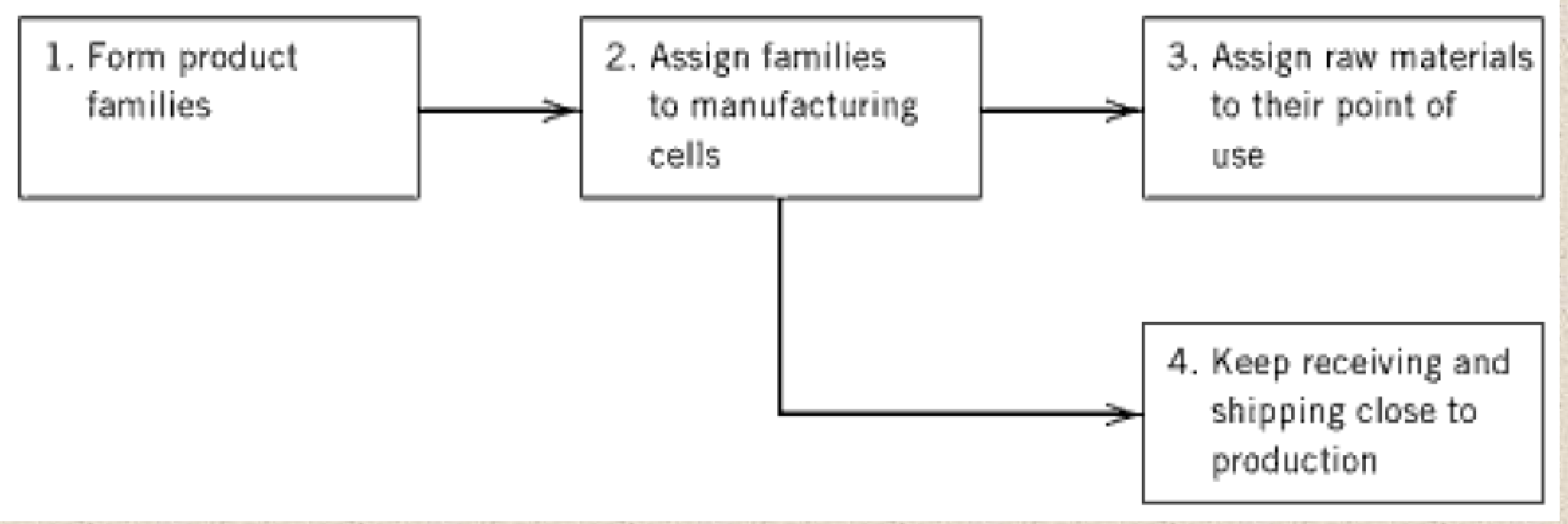
- Is used to gather verbal data, such as ideas and issues, and organize it into grouping

Issues in reducing manufacturing lead time

Facilities design	Equipment issues	Quality	Setup time	Scheduling
1. Form product families	1. Operator certification program	1. Provide training on how to use process documentation	1. Provide documentation on setup procedures	1. Provide visibility to daily product sequence
2. Assign families to cells	2. Sit technicians closer to production	2. Implement successive inspection with feedback	2. Locate fixtures and tooling close to machines	2. Do not authorize products for which the needed parts are not available
3. Assign raw mtl's to their point of use	3. Monitor breakdowns to predict future occurences	3. Develop mistake-proof devices	3. Provide training so operators can participate	3. Negotiate frequent and smaller lots to customers
4. Keep receiving and shipping close to production	4. Recruit enough technicians per shift	4. Develop capabilities for monitoring key machine parameters	4. Provide information on daily sequence	

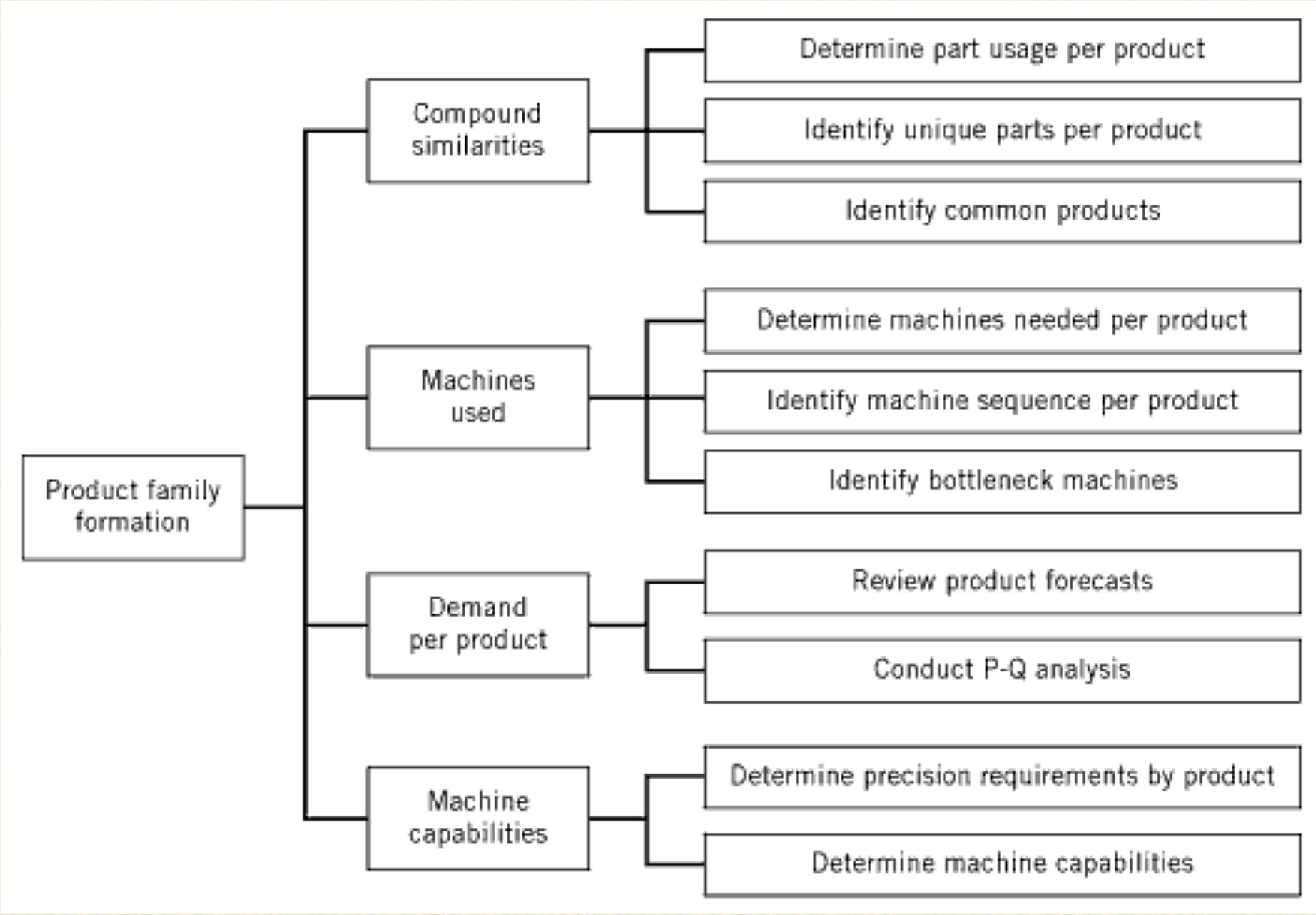
Interrelationship diagraph

- Is used to map the logical links among related items, trying to identify which items impact others the most. This graph helps us understand the logical sequence of steps for the facilities design.



Tree diagram

- Is used to map in increasing detail the actions that need to be accomplished in order to achieve a general objective.



Matrix diagram

- Organizes information such as characteristics, functions, and tasks into sets of items to be compared.
- Provides visibility to key contact on spesific issues and helps identify individuals who are assigned to too many teams.

Team\Participants	Joe	Mary	Jerry	Lou	Linda	Daisy	Jack
Part usage team	P	C	P	L			P
Machine use & cap team	L		C				P
Demand forecast team				P	C	L	

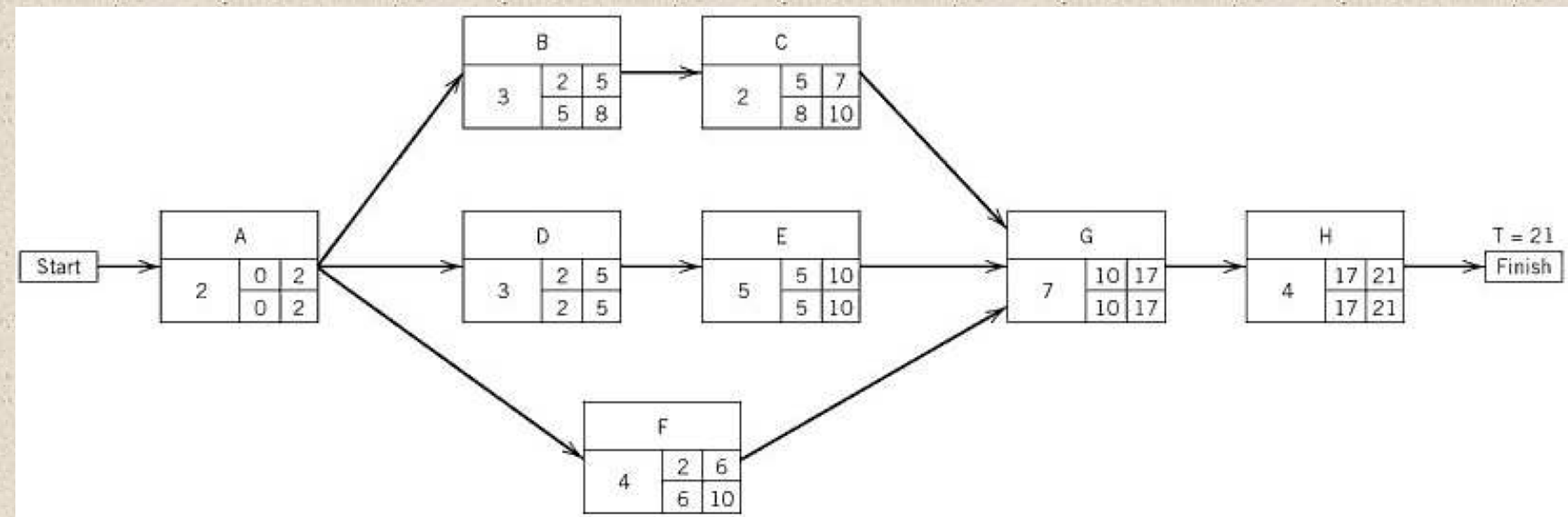
Note. L: Team Leader
C: Team Coordinator
P: Team Participant

Contigency diagram

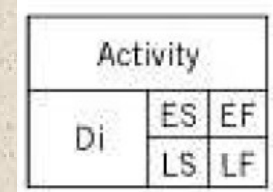
- Process decision program chart, maps conceivable events and contigencies that might occur during implementation.
- Is useful when the project being planned consists of unfamiliar tasks.

Activity network diagram

- Is used to develop a work schedule for the facilities design effort.
- Critical path method (CPM).
- Can be replaced by a Gant chart.



A: Schedule shutdown periods for equipment movement and installation
B: Interview, evaluate, select, and hire new employees
C: Train new employees
D: Interview, evaluate, and select equipment vendors
E: Order equipment
F: Interview, evaluate, select, and hire construction contractors
G: Meet to review installation plan (facilities design team, contractors, new employees, vendor representatives, and management)
H: Executive installation plan and test system



Di : Activity duration
ES: Early start
EF: Early finish
LS: Late start
LF: Late finish

Prioritization matrix

- In developing facilities design alternatives it is important to consider:
  a) Layout characteristics
     - Total distance travelled
     - Manufacturing floor visibility
     - Overall aesthetics of the layout
     - Ease of adding future business
  b) Material handling equipment
     - Use of current material handling equipment
     - Investment requirements on new equipment
     - Space and people requirements
  c) Unit load implied
     - Impact on WIP levels
     - Space requirements
     - Impact on material handling equipment
  d) Storage strategies
     - Space and people requirements
     - Impact on material handling equipment
     - Human factor risk
  e) Overall building impact
     - Estimated cost of the alternative
     - Opportunities for new business

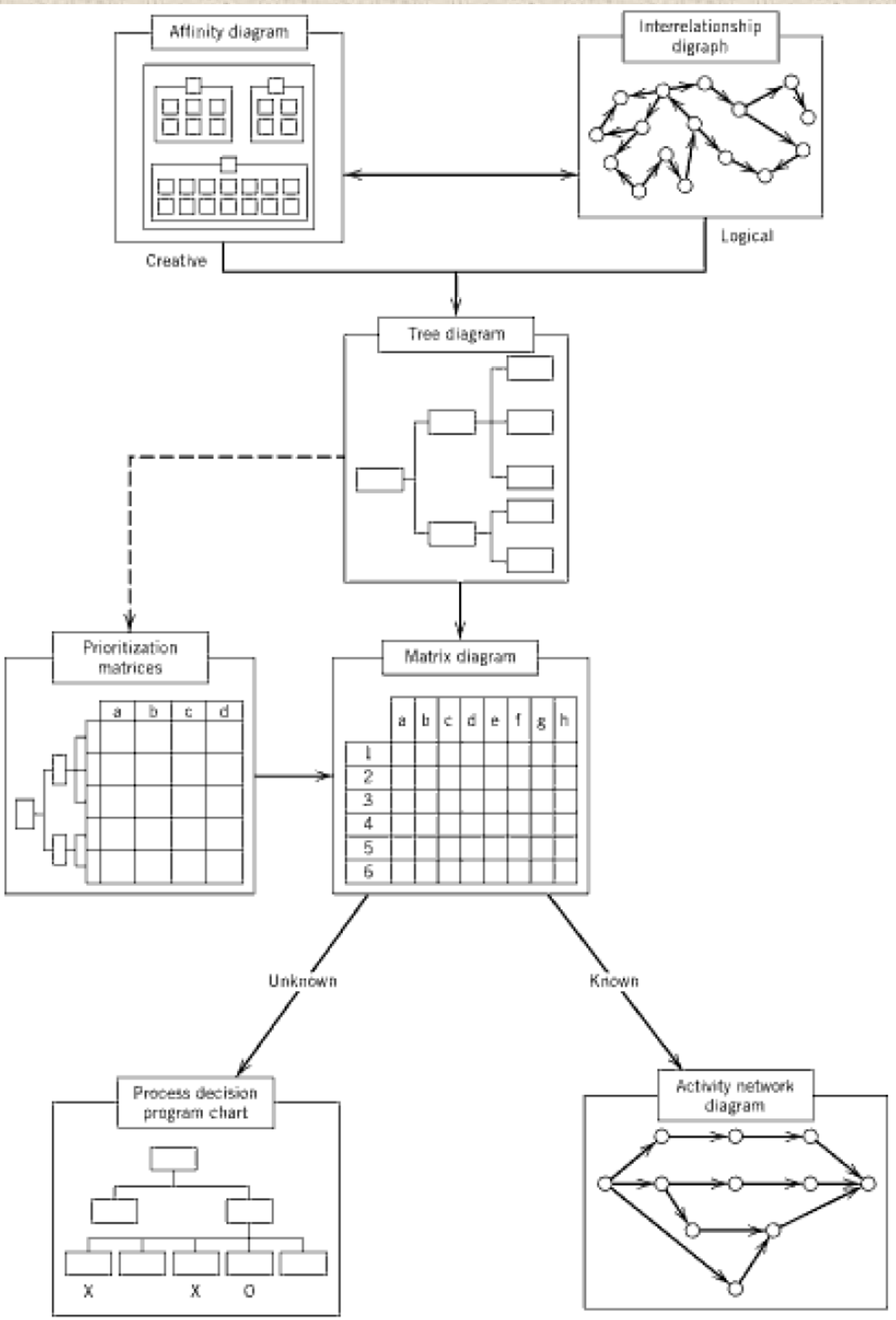
Prioritization matrix

- Is used to judge the relative importance of each criterion as compared to each other

	Criteria											
	A	B	C	D	E	F	G	H	I	J	K	Row totals (%)
A	1	5	10	5	1	1	1	1	1	5	1	32 (9.9)
B	1/5	1	5	1/5	1/5	1/10	1/5	1/5	1/10	1/5	1/5	7.6 (2.4)
C	1/10	1/5	1	1/10	1/10	1/10	1/5	1/5	1/10	1/10	1/10	2.3 (0.7)
D	1/5	5	10	1	1/5	1/5	1/5	1/5	1/10	1/5	1/10	17.4 (5.4)
E	1	5	10	5	1	1	5	5	1/5	1	1/5	34.4 (10.7)
F	1	10	10	5	1	1	5	5	1	1	1	41 (12.7)
G	1	5	5	5	1/5	1/5	1	5	1/5	1/5	1/58	23 (7.1)
H	1	5	5	5	1/5	1/5	5	1	1/10	1/5	1/5	22.9 (7.1)
I	1	10	10	10	5	1	5	10	1	1	5	59 (18.3)
J	1/5	5	10	5	1	1	5	5	1	1	5	39.2 (12.2)
K	1	5	10	10	5	1	5	5	1/5	1/5	1	43.4 (13.5)
Column total	7.7	56.2	86	51.3	14.9	6.8	32.6	37.6	5	10.1	14	322.2 Grand total

A. Total distance travelled
B. Manufacturing floor visibility
C. Overall aesthetics of the layout

G. Space requirements
H. People requirements
I. Impact on WIP levels



Logical application sequence of
The seven management and planning tool

References

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Thank You !