Assembly System Design Techniques

- Goals of this class
 - Introduce system design methods
 - Understand the things that must be considered
 - Look at two ways to approach it
 - Learn about SelectEquip

Assembly System Design Techniques

- Assembly system design algorithms exist
- They solve the "Equipment Selection and Task Assignment" problem
- Methods include dynamic programming, travelling salesman, mixed integer-linear programming, and a heuristic called ASDP
- These algorithms will design an assembly or other process line to meet average production requirements, adjusted for a fixed % uptime
- Detailed simulation is needed to verify production rate and study queues and other issues

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What to Model

- The tasks that need to be done
- The number of units needed per year
- What resources are available or applicable to a given task
 - What each resource costs to buy
 - What tool it needs for each task
 - How long it will take to do the task, change tools, etc
 - What is its uptime and other operating characteristics
- Time for transport from station to station
- Reuse of a resource for several tasks
- Reuse of tools at one station

History

- Heuristics by R E Gustavson at Draper and N H Cook at MIT in 1970s
- Solutions based on OR techniques by Prof Graves and OR Center students
 - Terry Huttner, 1977 mixed linear-integer programming
 - Bruce Lamar, 1979 bus routing algorithm
 - Carol Holmes, 1987 multiple products, dynamic programming
 - Curt Cooprider, 1989 uncertain demand, dynamic programming
- Holmes-Cooprider method reprogrammed by Mike Hoag, 2001.

System Selection Criteria

- Minimize annualized cost
 - = unit labor cost + annualized cost of capital
- Systems can be forced to be all manual, all robot, or all fixed automation just by removing unwanted resource classes
- A wide variety of preferences can be accommodated this way

Summary of Required Input

- Info about assembly resources with cost, operation time, and "rho" or installed cost factor
 - rho relates total cost to equipment cost
- Info about assembly tasks with operation time and tool number for each resource
- Annual production volume, labor cost, min acceptable rate of return, number of shifts available
 - Rate of return expressed in annualized cost factor

Title				Date				
Working days/year			Annualized cost					
Shifts available			Avg loaded labo					
		Station-station n	nove time (s)					
Resource data s	set name:			Task data set name				
	For each resour	ce:		When a resourc	e can be used:			
С	hardware Cost ((\$)						
rho	installed cost/ha	rdware cost		Operation	Tool			
е	% uptime expec	ted		time (s)	number			
v	operating/maint	enance rate (\$/hr)					
Тс	Tool change tim	e (s)		Hardwar	e cost			
Ms	Max # stations/	vorker						
NOTE: SEE FIG	3 14.8 OF CONC	URRENT DESIG	N AND PP 434-4	35				
Resource:								
	С	С	С	С	С			
	rho	rho	rho	rho	rho			
	e	e	e	e	e			
	v	v	v	v	v			
	Тс	Тс	Тс	Tc	Tc			
Task:	Ms	Ms	Ms	Ms	Ms			
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M=MEASURE									
S=MODIFY SHAPE									
A=ALIGN									

APPLICABLE TECHNOLOGY CHART

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FOR EACH RESOURCE:				ON A TASK:		
HARDWARE COST (\$)						
INSTALLED COST/HARDWAI	RE COST			TIME NUMBER		
OPERATING/MAINTENANCE	RATE (\$/h)					
SECONDS TOOL CHANGE TH MAXIMUM STATIONS PER W	VE Osker			HARDWARE COST		
,				(\$)		
RESOURCE	<u> </u>	<u>P29</u>	F30	<u>F60</u>		
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Applicable Technology Chart

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Assembly Planning Chart

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Basic Nominal Capacity Equations

operations/unit * # units/year = # ops/yr

ops/sec = # ops/yr * (1 shift/28800 sec)*(1 day/n shifts)*(1 yr/280 days)

cycle time = 1/(ops/sec) = required sec/op

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equipment capability = actual sec/op
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actual sec/op < required sec/op -> happiness
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required sec/op < actual sec/op -> misery (or multiple resources)

 Typical cycle times: 3-5 sec manual small parts

 5-10 sec small robot

 1-4 sec small fixed automation

 10-60 sec large robot or manual large parts

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How the Holmes-Cooprider Method Works

- The maximum takt or cycle time is calculated based on annual volume requirement and # shifts
- Each resource is tested to see if it can do one task without running out of time, two tasks, three tasks, etc.
- A network is built where pairs of nodes are tasks, and arcs are resources
- Each arc has a cost based on investment, tools, and labor (labor cost based on time used)
- The shortest path through the network is the string of selected resources and the tasks they will do

Network



Network Models of Assembly Systems

- Model of system as flows in a network
- Represents equilibrium state
- Based on probabilities and costs



- Outbound probabilities add to 1.0
- Equilibrium solution gives average cost to go through and average flow on each branch

Equations

 p_{ij} =pr of going from node i to node j c_{ij} =cost of going from node i to node j f_{ij} =flow from node i to node j y_i = total flow out of node i

 $f_{ij} = y_i p_{ij}$

where we must have

$$\sum_{j} p_{ij} = 1 \text{ for each } i$$

Conservation of flow at node j:

$$y_j = y_j p_{jj} + \sum_{k. j} y_k p_{kj} + x_j \quad \longrightarrow \quad$$

x_i=flow into node j from outside

p_{ii}=0

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Solution:



$$Y = P^{T}Y + X$$
$$Y = \left[I - P^{T}\right]^{-1}X$$
$$cost = \sum_{i} \sum_{j} f_{ij}c_{ij}$$

Example System: an assembly with two subassemblies and several test and rework stations



Network Equivalent of Example



A Build/repair Subassembly #1 and Test it
 B Build/repair Subassembly #2 and Test Both
 C Repair/rebuild #1 While Attached to #2

Matlab Solution

»P=zeros(8) »C=zeros(8) %Arc probabilities: »P(1,2)=1; »Y=inv(eye(8)-P')*X $Y \equiv$ »P(2,1)=.1; 1.1136 »p(2,3)=.9; »P(2,3)=.9; 1.1136 1.1162 »P(3,4)=1; »P(4,5)=1; 1.1390 »P(5,3)=.1; 1.1390 »P(5,1)=.002; 0.0253 P(5,6)=.02;0.0253 »P(5,8)=1-P(5,6)-P(5,3)-P(5,1); 1.0000 YY = [Y Y Y Y Y Y Y Y]»P(6,7)=1; P(7,4)=.9;»F=box(YY,P) »P(7,6)=.1; »X=[10000000]; »X=X' 11/16/2004 Asst Sys Des Tech © Daniel E Whitney

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Equilibrium Flows

$\mathbf{F} =$							
0.0000	1.1136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1114	0.0000	1.0023	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	1.1162	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	1.1390	0.0000	0.0000	0.0000
0.0023	0.0000	0.1139	0.0000	0.0000	0.0228	0.0000	1.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0253	0.0000
0.0000	0.0000	0.0000	0.0228	0.0000	0.0025	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Cost Solution

%Arc costs:

»C(1,2)=11;	
»C(2,1)=40;	%FF = total flow in system
»C(3,4)=20;	»FF=sum(sum(F))
»C(4,5)=2;	» FF=5.6720
»C(5,1)=50;	%EX=excess flow
»C(5,3)=10;	»EX=FF/5
»C(5,3)=10;	$\mathbf{E}\mathbf{X} =$
»C(5,6)=80;	1.1344
»C(6,7)=11;	Total flow without rework $= 5$
»C(7,6)=40;	Capacity devoted to rework = 13.44%
<pre>»cost=sum(sum(box(C,F)))</pre>	
cost =	
\$44.7608	
Cost without rework $=$ \$33	