Solution:

1. No information is available regarding the likely discount associated with any delay in delivery of an order, so the capacity of the facility can be determined without reference to any delays associated with the resulting cycle times, which can be very long if the minimum throughput required number of machines results in a very high utilization.
2. Only a single product was being produced, resulting in a single routing with dedicated machines, with the only decision being whether or not the overall layout should be straight-line or U-shaped. SDPI is used to solve machine layout problems that have multiple routings that use shared machines.
3. Advantages: Operators can easily move between machines. Can share loading/unloading equipment. Disadvantages: Can result in congestion during loading/unloading. May be difficult for products to make the required returns during transport down the line.
4. Low-bay is less costly than high-bay.
5. Single deep, sliding racks
6. They have the greatest storage depth per lane (except for block stacking, which is not actually a rack)
7. Pallets that are input first in a lane are blocked by later pallets, making them less accessible and FIFO more difficult.
8. Cantilever rack
9. AS/RS, A-frame, vertical lift module, or storage carousel
10. Loading and unloading occurs at opposite ends of a one-level lane of storage
11. Stacking frame
12. Sliding racks
13. Drive through
14. Zone picking uses multiple pickers for a single order, while batch picking uses a single picker for multiple orders
15. Most of the cost of piece picking us getting to/from the storage location, which is proportional to the number of different SKUs picked in an order and corresponds to the number of lines in the order.
16. The total cubic volume (cube) of an item may be less than the product of its dimensions, which may affect packing
17. More pick locations are available, but it takes longer to pick from locations above floor level.
18. Any three of: Paper (Pick-to-Paper), PDT display (Bar Code Scanning), spoken commands (Pick-to-Voice), LED display (Pick-to-Light)

19. In picking, containers of many items are used to form each order, while in putting, one container of an item is put into many orders.

20.

	Order								
Item	1	2	3	Cube				Cube Movement	
A	3	12	6	60	180	720	360	1260	
B	4	4	0	48	192	192	0	384	
C	6	12	12	180	1080	2160	2160	5400	
D	0	6	12	32	0	192	384	576	
					1452	3264	2904	2540	= cube per order

21. A-B,C,D = 0.2,0.5,0.1, B-C,D = 0.3,0.2, C-D = 0.2

X	8.166667								
Y	53								
Z	9.166667								
x	3								
y	3								
z	2								
L	2								
D	17								
H	4	= MIN(5,FLOOR(Z/z,1))							
LDH	136								
Inbound	A	B	C	Total					
wt	240	135	450						
unit/TL	136	136	111	= MIN(LDH,FLOOR(50000/wt,1))					
pct of A		85%	125%						
demand	15000	12750	18750						
yield	0.76								
	19736.84	12750	18750						
TL/yr	145.1238	93.75	168.9189						
Outbound									
cube	24	18	18	= xyz					
wt	210	135	450						
tons	1575	860.625	4218.75	6654.375	= wt*demand/2000				
density (s)	8.75	7.5	25	14.3568	= wt/cube				
f/s	180	114.75	168.75	463.5					
qmax				19.74059	= MIN(25,sagg*2750/2000)				
Customer	1	2	3	4					
	0.15	0.24	0.36	0.25					
tons (f)	998.1563	1597.05	2395.575	1663.594					
TL/yr	50.56364	80.90182	121.3527	84.27273	= f/qmax				
Location	Ash	Sta	WS	Gre	Dur	Ral	Wil	Total	
TL/yr	50.56364	145.1238	168.9189	121.3527	80.90182	84.27273	93.75	744.8837	
	50.56364	195.6875	364.6064	485.9591	566.8609	651.1337	744.8837	372.4418	
				(a)					
TL rate ($/mi)	2								
mi marker	50	150	190	220	270	295	420		
dist to facility	170	70	30	0	50	75	200		
distribution cost	17191.64			0	8090.182	12640.91		37922.73	(b)
hrs/yr	2000								
L/U (hr)	0.5	(te)							
TL/hr (ra)	0.372442	= (TL/yr)/(hr/yr)							
No Docks	1	= FLOOR(ra*te + 1,1)		(c)					

22.

23.

r		5%
N	(yrs)	15
IV	($)	41,000,000
SV	(%)	25
SV	($)	10,250,000
IVeff	($)	36,069,575
CcrEquip	($/yr)	3,475,025
Bldg Cost	($)	27,500,000
CcrBldg	($/yr)	1,375,000
sft/yr		250
hr/sft		8
Annual Demand	(q/yr)	18,000
Labor	($/hr)	15.00
No. Oper		45
Hrs/Yr/Oper		2,000
Direct Labor Cost	($/yr)	1,350,000
Indirect Labor	($/yr)	275,000
Total Labor Cost	($/yr)	1,625,000

X		8.166666667
Y		53
Z		9.166666667
x		4
y		3.5
z		2.5
L		2
D		15
H		3
LDH		90
wt		425
unit/TL		90
yield		0.78
lB demand		23,076.92
TL/yr		256.4102564
Circuity factor		1.20
GC distance	(mi)	722.69
Road distance	(mi)	867.23
Transport rate	($/ld-mi)	2.43
Transport cost	($/yr)	540,348.16
FOB origin unit cost		350.00
Procurement cost	($/yr)	8,617,271.23
Total cost	($/yr)	15,092,296.58
Average cost	($/q)	838.46

	dd	mm	ss		x (deg)	x (rad)	dd	mm	ss		y (deg)	y (rad)	d(rad)	d (mi)
Tampa	82	29	0	W	-82.48	-1.44	27	57	0	N	27.95	0.4878		
Richmond	77	28	0	W	-77.47	-1.352	37	32	0	N	37.533	0.6551	0.1827	722.69

24.

		UCB	NAR
r		0.10	0.10
N	(yrs)	15	15
IV	($)	25,000	30,000
SV	(%)	25	25
SV	($)	6,250	7,500
IVeff	($)	23,504	28,205
Ccr	($/yr/veh)	3,090	3,708
A		12	8
M		120,000	120,000
N		5,000	5,000
x		4.00	4.00
y		3.33	3.33
z		3.00	3.00
H		6	6
D		4	3
L(D)		7,396	9,028
TS(2-D)		571,957	505,568
Cross Aisle %		15%	15%
CS(2-D)		85,794	75,835
TS = TS + CS		657,751	581,403
Perimeter Cost		0	0
Perimeter		3,441	3,235
Area Cost		5	5
Bldg Cost	($)	3,288,755	2,907,016
CcrBldg	($/yr)	328,875	290,702

sft/yr		250	250
hr/sft		8	8
Speed	(mph)	7	7
	(ft/min)	616	616
TA	(ft^2)	657,751	581,403
d_Slots,0	(ft)	1147	1078
d_I/O,0	(ft)	0	0
d_SC	(ft/mov)	1147	1078
L/U time	(s)	25	35
T(SC)	(min/mov)	2.695270505	2.91721052
Annual Demand	(mov/yr)	500,000	500,000
	(hr/yr)	22460.59	24310.09
Fuel	($/hr)	2.00	2.00
Fuel Cost	($/yr)	44,921	48,620
Labor	($/hr)	12.00	12.00
No. Oper		15	16
Hrs/Yr/Oper		2,000	2,000
Labor Cost	($/yr)	360,000	384,000
Oper Cost	($/yr)	404,921	432,620
Annual Demand	(mov/hr)	250	250
Peak Demand	(mov/hr)	312.5	312.5
T(SC)	(hr/mov)	0.044921175	0.04862018
No. vehicles	(m)	15	16
Peak Util	(u)	0.935857814	0.9496128
Avg Util	(u)	0.748686251	0.75969024
Ccr	($/yr)	46,352.00	59,330.56
Total Cost	($/yr)	780,148.64	782,652.33
Average Cost	($/mov)	1.560297283	1.56530467

			sft/yr		500	
			hr/sft		8	
			Speed	(mph)	7	
				(ft/min)	616	
			TA	(ft^2)	2,214,409	
			d_Slots,0	(ft)	2104	
			d_I/O,0	(ft)	0	
r		0.05	d_SC	(ft/mov)	2104	
N	(yrs)	10	L/U time	(s)	35	
IV	($)	35,000	T(SC)	(min/mov)	4.583023664	
SV	(%)	25	Annual Demand	(mov/yr)	2,000,000	
SV	($)	8,750	Operating Hours	(hr/yr)	152767	
IVeff	($)	29,628	Fuel	($/hr)	2.75	
CcrTr	($/yr/veh)	3,837	Annual Hours	(hr/yr)	4000	
			Labor	($/yr)	15.00	
A		7	Other Move Workers		12	
M		636,000	Oper Cost	($/yr)	4,020,111	
N		4,800				
x		3.50	Annual Demand	(mov/hr)	500	
y		3.33	Peak Demand	(mov/hr)	625	
z		3.50	T(SC)	(hr/mov)	0.076383728	
H		5	No. vehicles	(m)	48	
D		7	Peak Util	(u)	0.994579788	
L(D)		20,503	Avg Util	(u)	0.795663831	
TA(2-D)		1,925,573				
Cross Aisle %		15%	CcrTr * m	($/yr)	184,175.76	
CS(2-D)		288,836				
TS = TS + CS		2,214,409	Total Move Cost	($/yr)	4,204,286.27	
Perimeter Cost		0	Average Move Cost	($/mov)	2.102143134	(a)
Perimeter		6,313				
Area Cost		15.50	Total Bldg Cost (CcrBldg)	($/yr)	1,716,167	
Bldg Cost	($)	34,323,346	No. of Slots (M)		636,000	
CcrBldg	($/yr)	1,716,167	Average Storage Cost	($/slot-yr)	2.69837627	(b)

25. Demand assumed uncorrected since it belongs to different customers

26. Dedicated = 15 + 20 + 18 = 53 locations, Randomized = 36 locations, Class-based = 26 + 20 = 46 locations

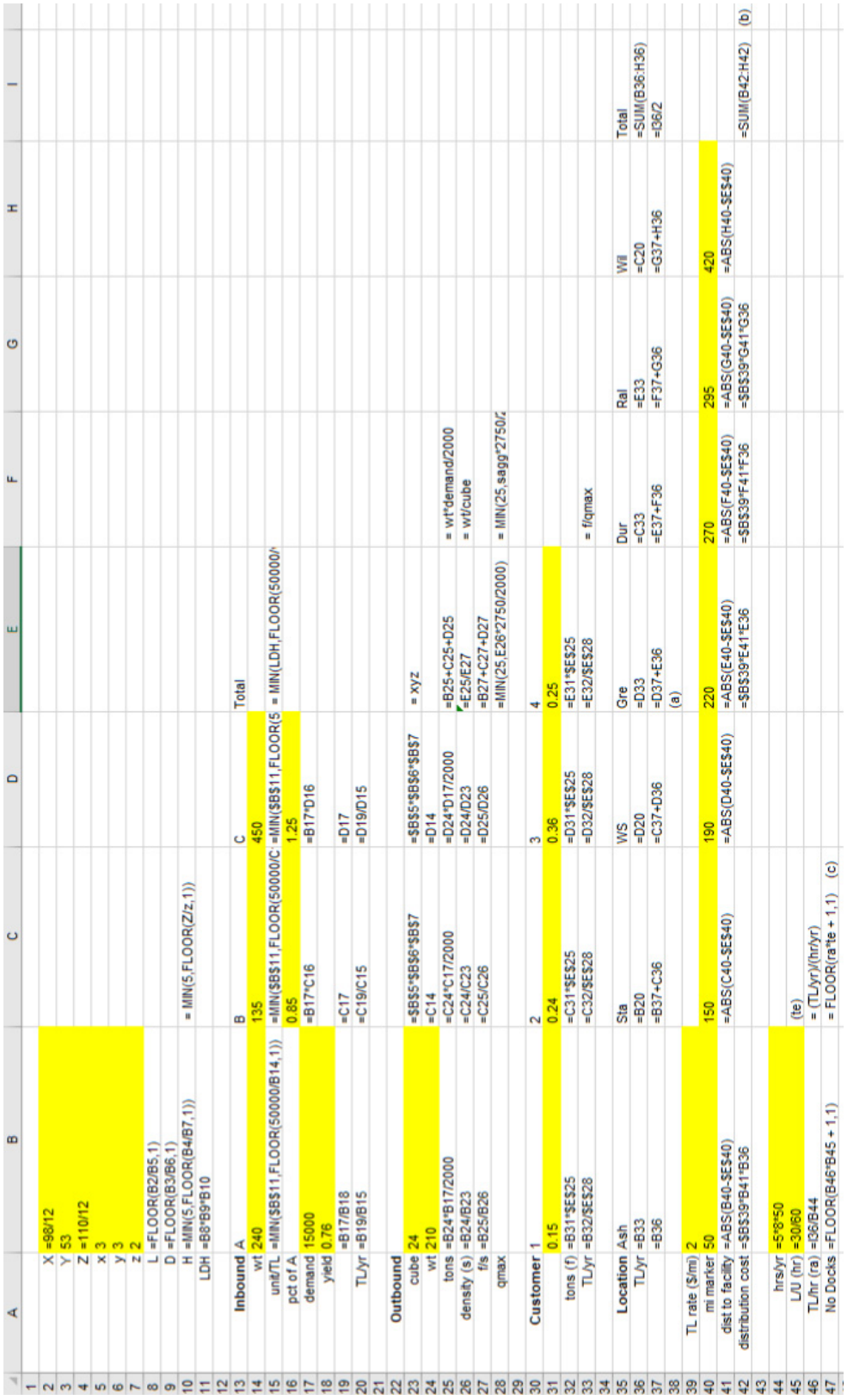
Period	A	B	C	ABC	AC	Total
1	10	12	7	29	17	
2	8	9	8	25	16	
3	9	20	7	36	16	
4	15	8	3	26	18	
5	11	5	2	18	13	
6	8	2	18	28	26	
	15	20	18	36	26	
Ded	15	20	18			53
Rand				36		36
AC-B		20			26	46

27. Given flow densities of 3.125, 3.25, and 3.167 for A, B, and C, respectively:

						A						
					A	C	A					
				A	C	C	C	A				
			A	C	C	B	C	C	A			
		C	C	B	B	I/0	B	C	C	A		

Formulas

22.



	A	B	C	D	E	F	G	H	I
1									
2	X	=98/12							
3	Y	53							
4	Z	=110/12							
5	x	3							
6	y	3							
7	z	2							
8	L	=FLOOR(B2/B5,1)							
9	D	=FLOOR(B3/B6,1)							
10	H	=MIN(5,FLOOR(B4/B7,1))	= MIN(5,FLOOR(Z/z,1))						
11	LDH	=B8*B9*B10							
12									
13	**Inbound**	A	B	C	Total				
14	wt	240	135	450					
15	unit/TL	=MIN($B$11,FLOOR(50000/B14,1))	=MIN($B$11,FLOOR(50000/C	=MIN($B$11,FLOOR(5	= MIN(LDH,FLOOR(50000/				
16	pct of A		0.85	1.25					
17	demand	15000	=B17*C16	=B17*D16					
18	yield	0.76							
19		=B17/B18	=C17	=D17					
20	TL/yr	=B19/B15	=C19/C15	=D19/D15					
21									
22	**Outbound**								
23	cube	24	=$B$5*$B$6*$B$7	=$B$5*$B$6*$B$7	= xyz				
24	wt	210	=C14	=D14					
25	tons	=B24*B17/2000	=C24*C17/2000	=D24*D17/2000	=B25+C25+D25	= wt*demand/2000			
26	density (s)	=B24/B23	=C24/C23	=D24/D23	=E25/E27	= wt/cube			
27	f/s	=B25/B26	=C25/C26	=D25/D26	=B27+C27+D27				
28	qmax				=MIN(25,E26*2750/2000)	= MIN(25,sagg*2750/			
29									
30	**Customer**	1	2	3	4				
31		0.15	0.24	0.36	0.25				
32	tons (f)	=B31*$E$25	=C31*$E$25	=D31*$E$25	=E31*$E$25				
33	TL/yr	=B32/$E$28	=C32/$E$28	=D32/$E$28	=E32/$E$28	= f/qmax			
34									
35	**Location**	Ash	Sta	WS	Gre	Dur	Ral	Wil	Total
36	TL/yr	=B33	=B20	=D20	=D33	=C33	=E33	=C20	=SUM(B36:H36)
37		=B36	=B37+C36	=C37+D36	=D37+E36	=E37+F36	=F37+G36	=G37+H36	=I36/2
38					(a)				
39	TL rate ($/mi)	2							
40	mi marker	50	150	190	220	270	295	420	
41	dist to facility	=ABS(B40-$E$40)	=ABS(C40-$E$40)	=ABS(D40-$E$40)	=ABS(E40-$E$40)	=ABS(F40-$E$40)	=ABS(G40-$E$40)	=ABS(H40-$E$40)	
42	distribution cost	=$B$39*B41*B36			=$B$39*E41*E36	=$B$39*F41*F36	=$B$39*G41*G36		=SUM(B42:H42) (b)
43									
44	hrs/yr	=5*8*50							
45	L/U (hr)	=30/60	(te)						
46	TL/hr (ra)	=I36/B44	= (TL/yr)/(hr/yr)						
47	No Docks	=FLOOR(B46*B45 + 1,1)	= FLOOR(ra*te + 1,1) (c)						

23.

	A	B	C
6	IVeff	($)	=C3-C5*(1+C1)^(-C2)
7	CcrEquip	($/yr)	=C6*(C1/(1-(1+C1)^(-C2)))
8			
9	Bldg Cost	($)	27500000
10	CcrBldg	($/yr)	=C9*C1
11			
12	sft/yr		250
13	hr/sft		8
14	Annual Demand	(q/yr)	18000
15	Labor	($/hr)	15
16	No. Oper		45
17	Hrs/Yr/Oper		=C12*8
18	Direct Labor Cost	($/yr)	=C15*C16*C17
19	Indirect Labor	($/yr)	275000
20	Total Labor Cost	($/yr)	=C18+C19
21			
22	X		=98/12
23	Y		53
24	Z		=110/12
25	x		=48/12
26	y		=42/12
27	z		=30/12
28	L		=FLOOR(C22/C25,1)
29	D		=FLOOR(C23/C26,1)
30	H		=MIN(6,FLOOR(C24/C27,1))
31	LDH		=C28*C29*C30
32			
33	wt		425
34	unit/TL		=MIN(C31,FLOOR(50000/C33,1))
35	yield		0.78
36	IB demand		=C14/C35
37	TL/yr		=C36/C34
38	Circuity factor		1.2
39	GC distance	(mi)	=O52
40	Road distance	(mi)	=C39*C38
41	Transport rate	($/ld-mi)	2.43
42	Transport cost	($/yr)	=C41*C40*C37
43	FOB origin unit cost		350
44	Procurement cost	($/yr)	=C43*C36+C42
45			
46	Total cost	($/yr)	=C7+C10+C20+C44
47	Average cost	($/q)	=C46/C14

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
49															
50		dd	nm	ss		x (deg)	x (rad)	dd	mm	ss		y (deg)	y (rad)	d(rad)	d (mi)
51	Tampa	82	29	0	W	=(B51+C51/60+D51/3600)	=F51*PI()/180	27	57	0	N	=(H51+I51	=L51*PI		
52	Richmond	77	28	0	W	=(B52+C52/60+D52/3600)	=F52*PI()/180	37	32	0	N	=(H52+I52	=L52*PI	=ACOS(SIN(M52)*SIN(M$51)+COS(M52	=N52*(3963.34 - 13.35*SIN((M

24.

	A	B	C	D
1			**UCB**	**NAR**
2	r		0.1	0.1
3	N	(yrs)	15	15
4	IV	($)	25000	30000
5	SV	(%)	25	25
6	SV	($)	=C4*C5/100	=D4*D5/100
7	IVeff	($)	=C4-C6*(1+C2)^(-C3)	=D4-D6*(1+D2)^(-D3)
8	Ccr	($/yr/veh)	=C7*(C2/(1-(1+C2)^(-C3)))	=D7*(D2/(1-(1+D2)^(-D3)))
9				
10	A		12	8
11	M		120000	120000
12	N		5000	5000
13	x		4	4
14	y		=40/12	=40/12
15	z		3	3
16	H		6	6
17	D		=FLOOR(SQRT((C10*(2*C11-C12))/(2*C12*C14*C16)) + 0.5,1)	=FLOOR(SQRT((D10*(2*D11
18	L(D)		=CEILING((C11+C12*C16*((C17-1)/2) + C12*(C16-1)/2)/(C17*C16),1)	=CEILING((D11+D12*D16*((D'
19	TS(2-D)		=C13*C18*(C14*C17+C10/2)	=D13*D18*(D14*D17+D10/2)
20	Cross Aisle %		0.15	0.15
21	CS(2-D)		=C19*C20	=D19*D20
22	TS = TS + CS		=C19+C21	=D19+D21
23	Perimeter Cost		0	0
24	Perimeter		=SQRT(C22/2)*6	=SQRT(D22/2)*6
25	Area Cost		5	5
26	Bldg Cost	($)	=C23*C24+C25*C22	=D23*D24+D25*D22
27	CcrBldg	($/yr)	=C26*C2	=D26*D2
28				
29	sft/yr		250	250
30	hr/sft		8	8
31	Speed	(mph)	7	7
32		(ft/min)	=C31*5280/60	=D31*5280/60
33	TA	(ft^2)	=C22	=D22
34	d_Slots,0	(ft)	=SQRT(2*C33)	=SQRT(2*D33)
35	d_I/O,0	(ft)	0	0
36	d_SC	(ft/mov)	=C34 + 2*C35	=D34 + 2*D35
37	L/U time	(s)	25	35
38	T(SC)	(min/mov)	=C36/C32 + 2*(C37/60)	=D36/D32 + 2*(D37/60)
39	Annual Demand	(mov/yr)	500000	500000
40		(hr/yr)	=C39*(C38/60)	=D39*(D38/60)
41	Fuel	($/hr)	2	2
42	Fuel Cost	($/yr)	=C40*C41	=D40*D41
43	Labor	($/hr)	12	12
44	No. Oper		=C52	=D52
45	Hrs/Yr/Oper		=C29*8	=D29*8
46	Labor Cost	($/yr)	=C43*C44*C45	=D43*D44*D45
47	Oper Cost	($/yr)	=C42+C46	=D42+D46
48				
49	Annual Demand	(mov/hr)	=C39/(C29*C30)	=D39/(D29*D30)
50	Peak Demand	(mov/hr)	=1.25*C49	=1.25*D49
51	T(SC)	(hr/mov)	=C38/60	=D38/60
52	No. vehicles	(m)	=FLOOR(C50*C51+1,1)	=FLOOR(D50*D51+1,1)
53	Peak Util	(u)	=C50*C51/C52	=D50*D51/D52
54	Avg Util	(u)	=C49*C51/C52	=D49*D51/D52
55				
56	Ccr	($/yr)	=C52*C8	=D52*D8
57				
58	Total Cost	($/yr)	=C47+C56 + C27	=D47+D56 + D27
59	Average Cost	($/mov)	=C58/C39	=D58/D39

25. (see slides for formulas)