Examination

TENTAMEN I:	Production and Logistics Planning
DATE:	2011-06-09
NUMBER OF HOURS:	5 Hours
GROUP:	Freestanding course
COURSE CODE:	KPP227
EXAMINATION CODE:	TEN1
HELPMEANS:	Calculator, Dictionary
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OBS: Rutat papper (Some Graph Paper)

Max points: 100
Point number for every task is within parenthesis.
For grade 3 at least 50 is required; grade 4 at least 65 and grade 5 at least 85

1 (8)

The table below shows the demand for a particular brand of fax machine in a department store in each of the last twelve weeks.

Week	1	2	3	4	5	6	7	8	9	10	11	12
Demand	12	15	19	23	27	30	32	33	37	41	49	58

- Calculate the four month moving average for weeks 4 to 12. What would be your forecast for the demand in week 13?
- Apply exponential smoothing with a smoothing constant of 0.2 to derive a forecast for the demand in week 13.
- Using the MSE (mean square error) which of the two forecasts for week 13 do you prefer and why?
- What other factors, not considered in the above calculations, might influence demand for the fax machine in week 13?

2 (6)

A manager has narrowed the search for a new facility location to four communities. The annual fixed and variable costs are shown in the Table below.

Location	Fixed cost/year	Variable cost/year
A	\$250,000	\$11
B	\$100,000	\$30
C	\$150,000	\$20
D	\$200,000	\$35

a. Plot the total-cost lines for these locations on a single graph.
b. Identify the range of output for which each alternative is superior (i.e. has the lowest total cost).
c. If expected output at the selected location is to be 8,000 units per year, which location would provide the lowest total cost?

3 (8)

The government is considering the economic benefits of a program of preventive swine flu vaccinations. If vaccinations are not introduced then the estimated cost to the government if the flu strikes in the next year is £7 million with a probability of 0.1, £10 million with a probability of 0.3, and £15 million with a probability of 0.6. It is estimated that such a program will cost £7 million and that the probability of flu striking in the next year is 0.75. One alternative open to the committee is to institute an "early-warning" monitoring scheme (costing £3 million) which will enable it to detect an outbreak of flu early and hence institute a rush vaccination program (costing £10 million because of the need to vaccinate quickly before the outbreak spreads).

Draw the decision tree for this problem and suggest what recommendations the committee should make to the government if their objective is to maximize expected monetary value (EMV).

4 (12)

Customers arrive one at a time, completely random, at an ATM at the rate of 6 per hour. Customers take an average of 4 minutes to complete their transactions, and historical data have shown that the service time closely follow the negative exponential distribution. Customers queue up on FIFO basis. Assume that there is only one ATM.

a. Find the following expected measures of performance for this system: The expected number of customers in the system, the expected number of customers waiting for service, the expected time in the system, and the expected time in the queue.
b. What is the probability that there are more than 5 people in the system at any random point in time?
c. What is the probability that the waiting time in the queue exceeds 10 minutes?
d. Given these results, do you think that management should consider adding another ATM?

5 (12)

Use the least cost method (LCM), Vogel's approximation (VAM), and the modified transportation method to find the least cost of the following transportation problem where the costs per unit are shown in the matrix below.

	Warehouses				
Factories	1	2	3	4	Amount available
1	19	30	50	10	7
2	70	30	40	60	9
3	40	8	70	20	18
Amount required	5	8	7	14	

6 (8)

A General Motors Buick plant manufactures several Buick models. The company has forecast its quarterly demands during the next four quarters, which are listed below. The plant can produce approximately 25 autos per quarter for each worker on staff. Workers receive an average of $15,000 per quarter in wages and benefits, and it costs $7,000 to hire and train a new worker and $10,000 to lay off a worker. Workers can be hired or laid off at the beginning of any quarter. GM expects to have 480 workers on staff and 2000 autos in inventory at the end of the current quarter. Any auto held in inventory at the end of a quarter incurs a holding cost of $1,000. Construct an aggregate plan for the next four quarters using the chase and level strategies and compute their total costs.

Quarter	Aggregate Demand
1	10,000
2	12,000
3	9,000
4	11,000

7 (5)

Demand for an item is normally distributed with a mean of 18 units per week and a standard deviation in weekly demand of 5 units. The lead-time is 2 weeks, and business operates 52 weeks per year. What P (time between intervals) approximates a 75 unit EOQ? What T is needed for a 90 percent cycle-service level? Answers are to be rounded to the nearest integer.

8 (8)

The BOMs for products A and B are shown in Table 1. Data from inventory records are shown in Table 2. The MPS calls for 85 units of product A to be completed in week 4 and 100 units to be completed in week 7 (the lead time is one week). The MPS for product B calls for 180 units to be completed in week 7 (the lead time is two weeks). Develop the material requirement plan for the next six weeks for items C, D, E, and F.

Item	Made of Number*Item	Item	Made of Number *Item
A	2*C 1*D	B	1*D 2*E
D	2*F 1*E	D	2*F 1*E
E	1*F	E	1*F

Table 1

Inventory Record Data

	Item			
Data Category	C	D	E	F
Lot sizing rule	FOQ =220	L4L	FOQ = 300	POQ = (P=2)
Lead time	3 weeks	2 weeks	3 weeks	2 weeks
Safety stock	20	0	0	80
Scheduled receipts	280 (week 1)	None	300 (week 3)	None
On-hand inventory	25	0	150	600

Table 2

9 (7)

Consider the following job times for a three-machine problem. Assume that the jobs are processed in the sequence A-B-C. Find the optimum sequence for processing the jobs below and show it on a Gantt chart for all three machines.

	Machines		
Job	A	B	C
1	10	6	18
2	14	4	10
3	8	6	14
4	16	8	6
5	12	4	4
6	14	0	16

10 (4)

a."Because organizations in the service sector do not manufacture products from raw materials, materials management concepts do not apply to them." Do you agree or disagree with this statement? Why?

b. Few, if any, products or services fit the EOQ assumption (e.g. no variation in demand, lead time, or supply) so how can the EOQ model provide guidance in managing real-world inventories?

11 (6)

An assembly line involves 9 tasks that require a total assembly time of 66 minutes.
The firm has determined that there are 480 productive minutes of work available per day. Furthermore, the production schedule requires that 40 units be completed as output from the assembly line each day.

Task	Performance time(m)	Predecessor(s)
A	10	-
B	11	A
C	5	B
D	4	B
E	12	A
F	3	C, D
G	7	F
H	11	E
I	3	G, H

a. Draw a precedence Diagram.
b. What cycle time results in the desired output rate?
c. Balance the line as best as you can.
d. What is the efficiency of your solution?

12 (4)

Three operations, A, H, and C are arranged in series. For an eight-hour shift, the effective capacities are 24, 18, and 20 units per day, respectively. What is the effective capacity of the system? To increase production, 33% overtime was authorized at operation H and 20% at operation C. Soon after the overtime was authorized, the average output rate for the system rose to 21 units per day, which is less than 24 units per day expected. Explain three likely reasons the average output rate fell below expectations.

13 (6)

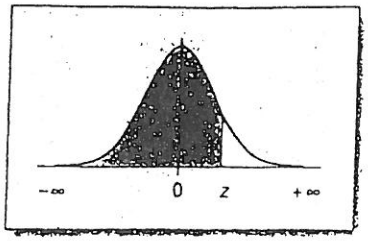
The maintenance department of a hospital uses about 816 cases of liquid cleanser annually. Ordering costs are $12, carrying costs are $4 per case a year, and the new price schedule indicates that orders of less than 50 cases will cost $20 per case, 50 to 79 cases will cost $18 per case, 80 to 99 cases will cost $17 per case, and larger orders will cost $16 per case. Determine the optimal order quantity and the total minimum cost.

14 (6)

a. How do we classify products for logistics purposes and how can they be linked to the product life cycle and the 80-20 curve? Explain in details.
b. What are the most important product characteristics that can influence logistics? Explain in details.

Good Luck
Sabah Audo

Appendix 1: Normal Distribution



	.00	01	02	03	04	05	06	07	.08	09
0	5000	5040	5080	5120	5160	.5199	.5239	5279	.5319	5359
1	5398	.5438	5478	.5517	.5557	5596	.5636	.5675	.5714	5753
2	.5793	5832	5871	5910	.5948	.5987	6026	.6064	.6103	6141
3	6179	6217	6255	6293	6331	.6368	6406	.6443	6480	6517
4	6554	6591	6628	6664	6700	6736	.6772	.6808	6844	6879
5	6915	6950	6985	7019	7054	.7088	7123	.7157	.7190	7224
6	7257	7291	7324	7357	.7389	.7422	7454	.7486	7517	7549
7	7580	7611	7642	.7673	.7704	.7734	7764	7794	7823	7852
8	7881	7910	7939	7967	7995	.8023	8051	.8078	8106	8133
9	8159	8186	8212	8238	8264	.8289	8315	8340	.8365	8389
1 0	8413	8438	8461	8485	8508	8531	8554	8577	8599	.8621
1 1	8643	8665	8686	8708	8729	8749	8770	.8790	8810	8830
1 2	8849	8869	8888	8907	8925	8944	8962	8980	8997	9015
1 3	9032	9049	9066	9082	9099	9115	9131	9147	9162	9177
1 4	9192	9207	9222	9236	9251	9265	9279	9292	9306	9319
1 5	9332	9345	9357	9370	9382	9394	9406	9418	9429	9441
1 6	9452	.9463	9474	9484	9495	9505	9515	9525	.9535	.9545
1 7	9554	9564	9573	9582	.9591	9599	9608	9616	9625	9633
1 8	9641	9649	9656	9664	9671	9678	9686	9693	9699	.9706
1 9	.9713	9719	9726	9732	.9738	9744	.9750	9756	9761	9767
2 0	9772	9778	.9783	9788	9793	9798	.9803	.9808	9812	9817
2 1	.9821	9826	9830	9834	.9838	9842	.9846	.9850	.9854	9857
2 2	9861	.9864	9868	.9871	9875	9878	.9881	.9884	.9887	9890
2 3	.9893	.9896	9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2 4	.9918	.9920	9922	.9925	.9927	.9929	9931	9932	9934	.9936
2 5	9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2 6	9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	9964
2 7	9965	.9966	.9967	.9968	.9969	.9970	9971	9972	9973	9974
2 8	9974	.9975	9976	.9977	.9977	9978	9979	9979	.9980	.9981
2 9	9981	9982	9982	9983	.9984	.9984	9985	.9985	.9986	9986
3 0	9987	9987	9987	9988	.9988	9989	9989	9989	.9990	9990
3 1	.9990	.9991	9991	9991	9992	9992	.9992	9992	9993	9993
3 2	9993	9993	9994	9994	.9994	.9994	9994	9995	9995	9995
3 3	9995	9995	9995	9996	.9996	9996	9996	9996	9996	9997
3 4	9997	9997	9997	9997	9997	9997	9997	9997	9997	9998

1. The four week moving av. for weeks 5-13 is:

$W_5 = (23+19+15+12)/4 = 17.25$

$W_6 = (27+23+19+15)/4 = 21$

$W_7 = (30+27+23+19)/4 = 24.75$

$W_8 = (32+30+27+23)/4 = 28$

$W_9 = (33+32+30+27)/4 = 30.5$

$W_{10} = (37+33+32+30)/4 = 33$

$W_{11} = (41+37+33+32)/4 = 35.75$

$W_{12} = (49+41+37+33)/4 = 40$

$W_{13} = (58+49+41+37)/4 = 46.25 \simeq 46$

Exp. Smoothing

$W_2 = 12$

$W_3 = 0.2(15) + 0.8(12) = 12.6$

$W_4 = 0.2(19) + 0.8(12.6) = 13.88$

$W_5 = 0.2(23) + 0.8(13.88) = 15.704$

$W_6 = 0.2(27) + 0.8(15.704) = 17.963$

$W_7 = 0.2(30) + 0.8(17.963) = 20.370$

$W_8 = 0.2(32) + 0.8(20.37) = 22.696$

$W_9 = 0.2(33) + 0.8(22.696) = 24.757$

$W_{10} = 0.2(37) + 0.8(24.757) = 27.206$

$W_{11} = 0.2(41) + 0.8(27.206) = 29.965$

$W_{12} = 0.2(49) + 0.8(29.965) = 33.772$

$W_{13} = 0.2(58) + 0.8(33.772) = 38.616$

MSE moving Av. $= [(17.25-27)^2 + \dots + (40-58)^2]/8$

$= 107.43$

MSE Exp. Sm. $= [(12-15)^2 + \dots + (33.772-58)^2]/11$

1. = 176.05

We see that MSE for the Moving Av. is lower. Hence we prefer the forecast of 46 that has been produced by the Moving Average.

<u>Other factor</u>

- seasonal demand
- advertising
- price changes, both this brand and other brands
- general economic situation
- new technology

2.

Fixed and variable costs for four potential plant locations are shown below:

Location	Fixed Cost per Year	Variable Cost per Unit
A	$250,000	$11
B	100,000	30
C	150,000	20
D	200,000	35

a. Plot the total-cost lines for these locations on a single graph.

b. Identify the range of output for which each alternative is superior (i.e., has the lowest total cost).

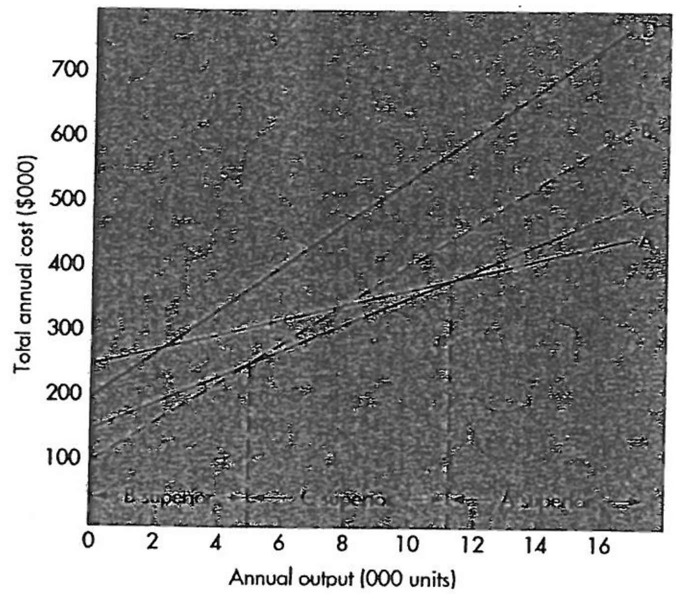
c. If expected output at the selected location is to be 8,000 units per year, which location would provide the lowest total cost?

Solution

a. To plot the total-cost lines, select an output that is approximately equal to the expected output level (e.g., 10,000 units per year). Compute the total cost for each location at that level:

	Fixed Cost	+	Variable Cost	=	Total Cost
A	$250,000	+	$11(10,000)	=	$360,000
B	100,000	+	30(10,000)	=	400,000
C	150,000	+	20(10,000)	=	350,000
D	200,000	+	35(10,000)	=	550,000

Plot each location's fixed cost (at Output = 0) and the total cost at 10,000 units; and connect the two points with a straight line. (See the accompanying graph.)



b. The *approximate* ranges for which the various alternatives will yield the lowest costs are shown on the graph. Note that location D is never superior. The *exact* ranges can be determined by finding the output level at which lines B and C and lines C and A cross. To do this, set their total cost equations equal and solve for Q, the break-even output level. Thus, for B and C:

$$\underset{\text{(B)}}{\$100{,}000 + \$30Q} = \underset{\text{(C)}}{\$150{,}000 + \$20Q}$$

Solving, you find $Q = 5{,}000$ units per year.

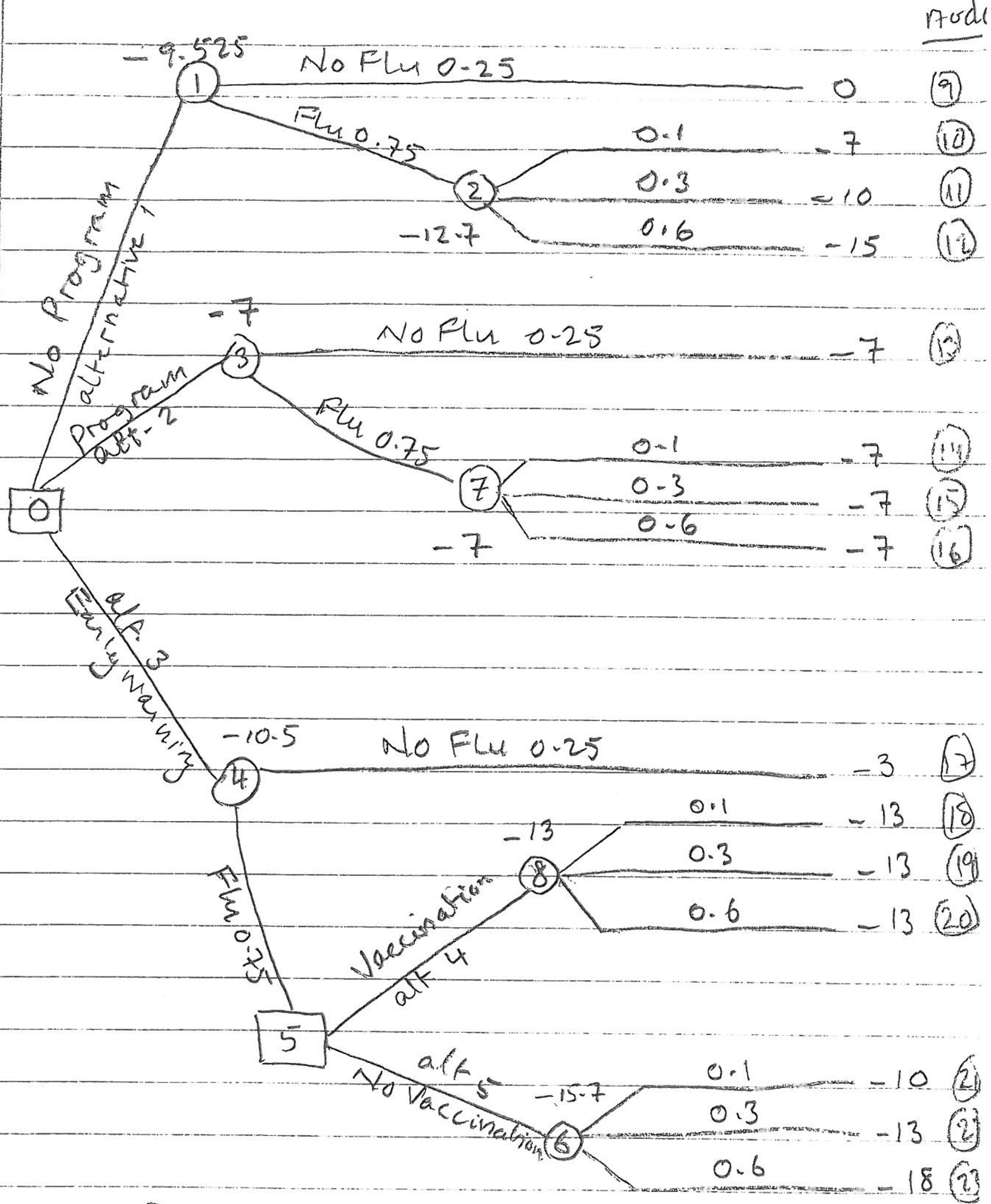
For C and A:

$$\underset{\text{(C)}}{\$150{,}000 + \$20Q} = \underset{\text{(A)}}{\$250{,}000 + \$11Q}$$

Solving, $Q = 11{,}111$ units per year.

c. From the graph, you can see that for 8,000 units per year, location C provides the lowest total cost.

3.



Node (2) $0.1(-7) + 0.3(-10) + 0.6(-15) = -12.7$

" (1) $0.2(0) + 0.75(-12.7) = -9.525$

" (7) $0.1(-7) + 0.3(-7) + 0.6(-7) = -7$

" (3) $0.25(-7) + 0.75(-7) = -7$

" (8) $0.1(-13) + 0.3(-13) + 0.6(-13) = -13$

(6) $0.1(-10) + 0.3(-13) + 0.6(-18) = -15.7$

3. node (9) we carry no program and flu does not strike
Total revenue = 0
" cost = 0
" profit = 0
node (10) we carry out no program and flue strikes costing the government of 7m
Total revenue = 0
" cost = 7
" profit = -7
node (11) and (12) similar to the case above giving a total profit of -10 and -15 respectively
node (13) we carry a program costing 7 and flu does not strike
Total revenue = 0
" cost = 7
" profit = -7
node (14) we carry a program costing 7 and flu strikes. Now we would have lost 7 with this flu outbreak but because of the program we do not.
The key here is to regard the 7 m paid for the program as an insurance which reimburses the government for whatever losses are suffered as a result of flu striking. Hence we have
Total revenue = 7 (reimbursement)
" cost = 7 (cost of program) + 7 (losses due to flu striking)
" profit = -7

3. node (15) and (16) similar to the case above where we carry out a program costing 7 and this insures us against losses

node (15) Total profit = -7

" (16) " " = -7

node (17) we carry out an early warning program costing 3 and flu does not strike giving

Total revenue = 0

" cost = 3

" profit = -3

nodes (18), (19) and (20) we carry out an early warning program costing 3, flu strikes and we have decided to vaccinate costing 10. Hence for a total cost of 13 we are insured against losses so that we have

nod (18) Total profit = -13

" (19) " " = -13

" 20 " " = -13

node (21), (22), and (23) we carry out an early warning program costing 3, flu strikes but we decide not to vaccinate, leading to costs of 7, 10, 15. Hence

node (21) Total profit = -10

" (22) " " = -13

" (23) " " = -18

3.

Hence node (5) we have two alternative

vaccination − 13

No " − 15.7

The best alternative here is to vaccinate with EMV of −13

node (4) 0.25(−3) + 0.75(−13) = −10.5

node (0) we have the three alternatives

- No program EMV = − 9.525
- Program EMV = − 7
- Early warning EMV = − 10.5

Hence the best alternative is alternative 2, institute a program costing £7, leading to an EMV of − £7m.

4.

the input process is a Poisson process. The arrival rate is $\lambda = 6$ per hour. The mean service time is 4 minutes = 1/15 hour, so that the service rate is $\mu = 15$ per hour. The utilization rate is $\rho = \lambda/\mu = 6/15 = 2/5 = .4$.

a. $L = \rho/(1 - \rho) = (2/5)/(3/5) = 3/4\ (= 0.6667)$.
   $L_q = \rho L = (2/5)(2/3) = 4/15\ (= 0.2667)$.
   $W = L/\lambda = (2/3)/6 = 2/18 = 1/9$ hour (6.6667 minutes).
   $W_q = L_q/\lambda = (4/15)/6 = 4/90 = 2/45$ hour (2.6667 minutes).

b. Here we are interested in $P\{L > 5\}$.
   In general,

$$P\{L > k\} = \sum_{n=k+1}^{\infty} P_n = \sum_{n=k+1}^{\infty} (1 - \rho)\rho^n = (1 - \rho)\sum_{n=k+1}^{\infty} \rho^n$$

$$= (1 - \rho)\rho^{k+1}(1/(1 - \rho)) = \rho^{k+1}.$$

   Hence, $P\{L > 5\} = \rho^6 = (0.4)^6 = 0.0041$.

c. Here we are interested in $P\{W_1 > 1/6\}$.

$$P\{W_q > t\} = \rho e^{-(\mu-\lambda)t} = 0.4e^{-(15-6)(1/6)} = 0.4e^{-1.5} = 0.0892.$$

d. The answer is not obvious. Looking at the expected measures of performance, it would appear that the service provided is reasonable. The expected number of customers in the system is lessΩ than one and the average waiting time in the queue is less than 3 minutes. However, from part (c) we see that the proportion of customers having to wait more than 10 minutes for service is almost 10 percent. This means that there are probably plenty of irate customers, even though on average the system looks good. This illustrates a pitfall of only considering expected values when evaluating queuing service systems. ■

5. Least Cost Method (LCM)

	8/70	80	70	~~14~~ 7 0	
0 ~~7~~	19	30	50	7 | 10	–
2 ~~9~~	2 | 70	30	7 | 40	60	–
0 ~~3 10 18~~	3 | 40	8 | 8	70	7 | 20	–
		–	–	–	

2 × 70 = 140
3 × 40 = 120
8 × 8 = 64
7 × 40 = 280
7 × 10 = 70
7 × 20 = 140

Total Cost = 814

VOGEL'S Approximation Method (VAM)

	5 0	8 0	~~7~~ 0	~~14~~ ~~4~~ 2	1	2	3	4	5
0 ~~2~~ ~~7~~	5 | 19	30	50	2 | 10	9	9	40	40	–
0 ~~2~~ ~~9~~	70	30	7 | 40	2 | 60	10	20	20	20	20
0 10 ~~18~~	40	8 | 8	70	10 | 20	12	20	50	–	–
1	21	22	10	10					
2	21	–	10	10					
3	–	–	10	10					
4	–	–	10	50					
5	–	–	10	–					

5 × 19 = 95
2 × 10 = 20
7 × 40 = 280
2 × 60 = 120
8 × 8 = 64
10 × 20 = 200

Total Cost = 779

5.

1

	5	8	7	14	
7	[19] 5	[30] 2	[50] (10)	[10] (20)	0
9	[70] (51)	[30] 6⁻	[40] 3⁺	[60] (70)	0
18	[40] (−9)	[8] (−52)⁺	[70] 4⁻	[20] 14	30
	19	30	40	−10	

5 X 19 = 95
2 X 30 = 60
6 X 30 = 180
3 X 40 = 120
4 X 70 = 280
14 X 20 = 280

Cost = 1015

2

	5	8	7	14	
7	[19] 5	[30] 2⁻	[50] (10)	[10] (−32)⁺	0
9	[70] (51)	[30] 2	[40] 7	[60] (18)	0
18	[40] (43)	[8] 4⁺	[70] (52)	[20] 14⁻	−22
	19	30	40	42	

5 X 19 = 95
2 X 30 = 60
2 X 30 = 60
7 X 40 = 280
4 X 8 = 32
14 X 20 = 280

Cost = 807

3

	5	8	7	14	
7	[19] 5	[30] (32)	[50] (42)	[10] 2	0
9	[70] (19)	[30] 2	[40] 7	[60] (18)	32
18	[40] (11)	[8] 6	[70] (52)	[20] 12	10
	19	−2	8	10	

5 X 19 = 95
2 X 10 = 20
2 X 30 = 60
7 X 40 = 280
6 X 8 = 48
12 X 20 = 240

Cost = 743

6.

Quarter	Aggregate Demand
1	10,000
2	12,000
3	9,000
4	11,000

Solution:

(a) *Chase Demand Strategy* For each quarter we determine the number of workers needed to meet the demand in that quarter exactly Then we adjust the workforce accordingly

Qt	Aggregate Demand (units)	Planned Output (units)	Workers on Staff	Workers Hired	Workers Laid Off	Inventory (units)
0			480			2000
1	10,000	8,000	320	0	160	0
2	12,000	12,000	480	160	0	0
3	9,000	9,000	360	0	120	0
4	11,000	11,000	440	80	0	0
Totals	(qts. 1–4)		1600	240	280	0

Salaries	1600 workers × $15,000/qt	= $24,000,000
Hiring cost	240 workers × $7,000	= $ 1,680,000
Layoff cost	280 workers × $10,000	= $ 2,800,000
Inventory cost	0 units × $1,000/unit =	0
Total cost		$28,480,000

(b) *Level Strategy*. For each quarter we compute the net cumulative requirements and the number of workers needed to make the cumulative requirements

Qt	Net Cumulative Requirements	Workers Needed to Make Cum. Req.
1	8,000	320.00
2	20,000	400.00
3	29,000	386 67
4	40,000	400.00

The largest number of workers ever needed is 400, so we will reduce the workforce to 400 and keep it there

Qt	Aggregate Demand (units)	Planned Output (units)	Workers on Staff	Workers Hired	Workers Laid Off	Inventory (units)
0			480			2000
1	10,000	10,000	400	0	80	2000
2	12,000	10,000	400	0	0	0
3	9,000	10,000	400	0	0	1000
4	11,000	10,000	400	0	0	0
Totals	(qts 1–4)		1600	0	80	3000

Salaries	1600 workers x $15,000/qt	= $24,000,000
Hiring cost	0 workers x $7,000	= $ 0
Layoff cost	80 workers x $10,000	= $ 800,000
Inventory cost	3000 units x $1,000/unit =	$ 3,000,000
Total cost		$27,800,000

7.

Solution We first define D and then P. Here, P is the time between reviews, expressed as a multiple (or fraction) of time interval t ($t = 1$ week because the data are expressed as demand *per week*):

$$D = (18 \text{ units/week})(52 \text{ weeks/year}) = 936 \text{ units}$$

$$P = \frac{\text{EOQ}}{D}(52) = \frac{75}{936}(52) = 4.2, \quad \text{or} \quad 4 \text{ weeks}$$

With $d = 18$ units per week, we can also calculate P by dividing the EOQ by d to get $75/18 = 4.2$, or 4 weeks. Hence we would review the birdfeeder inventory

:very 4 weeks. We now find the standard deviation of demand over the protection nterval ($P + L = 6$):

$$\sigma_{P+L} = \sigma_t \sqrt{P + L} = 5\sqrt{6} = 12 \text{ units}$$

Before calculating T, we also need a z value. For a 90 percent cycle-service level, $z = 1.28$ (see the Normal Distribution appendix). We now solve for T:

$$T = \text{Average demand during the protection interval} + \text{Safety stock}$$
$$= d(P + L) + z\sigma_{P+L}$$
$$= (18 \text{ units/week})(6 \text{ weeks}) + 1.28(12 \text{ units}) = 123 \text{ units}$$

Every four weeks we would order the number of units needed to bring inventory position IP (counting the new order) up to the target inventory level of 123 units. The safety stock for this P system is $1.28(12) = 15$ units, compared to only 9 units for the Q system.

8.

Item: A	Week	1	2	3	4	5	6	7	8
MPS Quantity (due)					85			100	
MPS Quantity (release)				85			100		

Item: B	Week	1	2	3	4	5	6	7	8
MPS Quantity (due)								180	
MPS Quantity (release)						180			

Item: C
Description:
Lot Size: FOQ = 220
Lead Time: 3 weeks
Safety Stock: 20 units

Week		1	2	3	4	5	6	7	8
Gross requirements				170			200		
Scheduled receipts		280							
Projected on hand	25	305	305	135	135	135	155	155	155
Planned receipts							220		
Planned order releases				220					

Item: D
Description:
Lot Size: L4L
Lead Time: 2 weeks
Safety Stock: 0 units

Week		1	2	3	4	5	6	7	8
Gross requirements				85		180	100		
Scheduled receipts									
Projected on hand	0	0	0	0	0	0	0	0	0
Planned receipts				85		180	100		
Planned order releases		85		180	100				

Item: E
Description:
Lot Size: FOQ = 300
Lead Time: 3 weeks
Safety Stock: 0 units

Week		1	2	3	4	5	6	7	8
Gross requirements		85		180	100	360			
Scheduled receipts				300					
Projected on hand	150	65	65	185	85	25	25	25	25
Planned receipts						300			
Planned order releases			300						

Item: F
Description:
Lot Size: POQ = 2
Lead Time: 2 weeks
Safety Stock: 80 units

Week		1	2	3	4	5	6	7	8
Gross requirements		170	300	360	200				
Scheduled receipts									
Projected on hand	600	430	130	280	80	80	80	80	80
Planned receipts				510					
Planned order releases		510							

9.

Job	M_1	M_2	M_3
1	10	6	18
2	14	4	10
3	8	6	14
4	16	8	6
5	12	4	4
6	14	0	16

$\min t_{i1} = \min\{t_{11}, t_{21}, t_{31}, t_{41}, t_{51}, t_{61}\} = 8$
$\max t_{i2} = \max\{t_{12}\ t_{22}, t_{32}, t_{42}, t_{52}, t_{62}\} = 8$

Since the condition of
$\min t_{i1} \geq \max t_{i2} \quad i = 1, 2, \ldots, 6$
or $\min t_{i3} \geq \max t_{i2} \quad i = 1, 2, \ldots, 6$
is satisfied, we can apply Johnson's algorithm

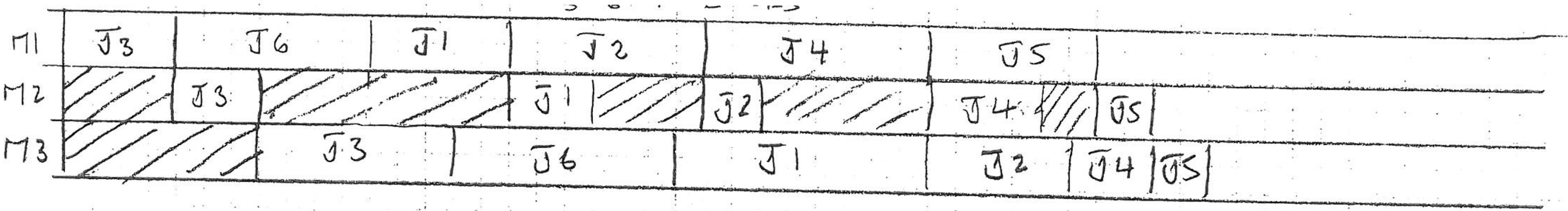
Job	M_1'	M_2'
1	16	24
2	18	14
3	14	20
4	24	14
5	16	8
6	14	16

$M_1' = t_{i1} + t_{i2}$
$M_2' = t_{i2} + t_{i3}$

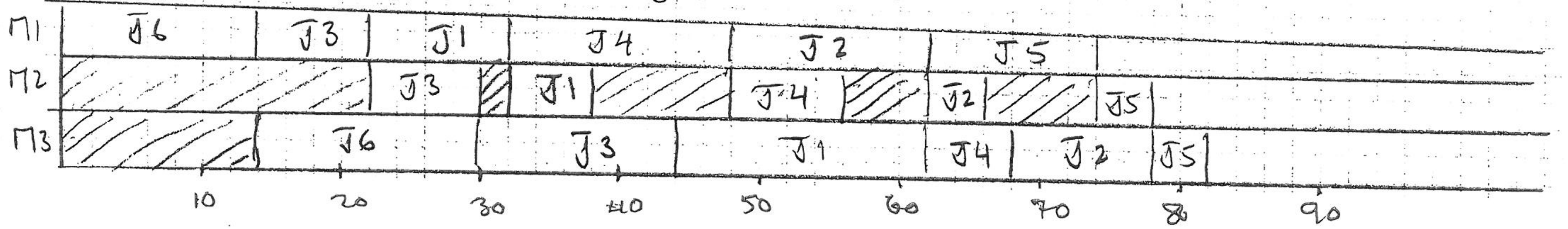
9. Upon applying Johnson's algorithm, it is found that the optimal job sequences are

3 - 6 - 1 - 2 - 4 - 5   6 - 3 - 1 - 2 - 4 - 5

3 - 6 - 1 - 4 - 2 - 5   6 - 3 - 1 - 4 - 2 - 5


M1
M2
M3
J3
J6
J1
J2
J4
J5
J3
J1
J2
J4
J5
J3
J6
J1
J2
J4
J5

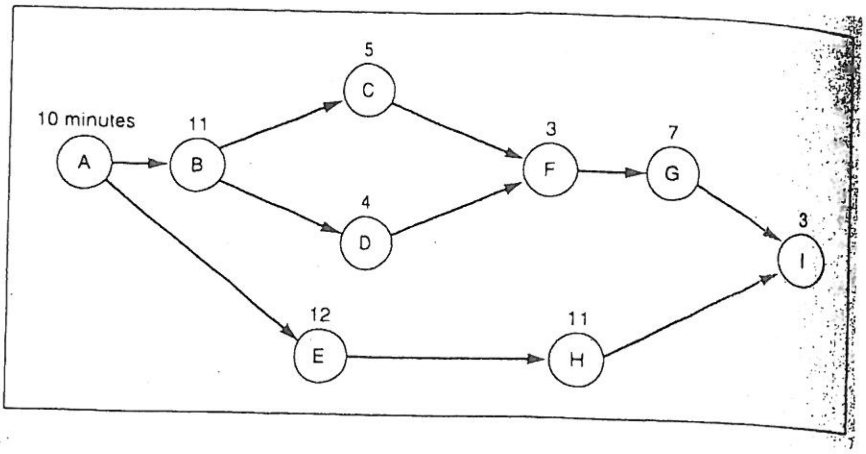
6-3-1-4-2-5


M1
M2
M3
J6
J3
J1
J4
J2
J5
J3
J1
J4
J2
J5
J6
J3
J1
J4
J2
J5
10
20
30
40
50
60
70
80
90

10. a. Materials management concepts apply to service organizations in the same way as to manufacturing organizations. The materials management decisions such as staffing plan, work-force schedule, inventory control (44 percent of the economy's inventory is held by wholesalers and retailers alone), operations scheduling, and purchasing are as important for the efficient management of service organizations as they are for manufacturing organizations.

b. It is true that very few actual situations are simple and well behaved enough to comply with the *EOQ* assumptions. Nevertheless, *EOQ* is often a reasonable first estimate of average lot size. Also, by adjusting the *EOQ* model to reflect the various changes in the basic assumptions, a planner can make more realistic decisions in managing inventories. Most of all, the *EOQ* concept provides valuable information about the structural relationships among the related variables. It provides a means to estimate the directions in which inventories will change in response to various changes in the cost and demand parameters.

11.

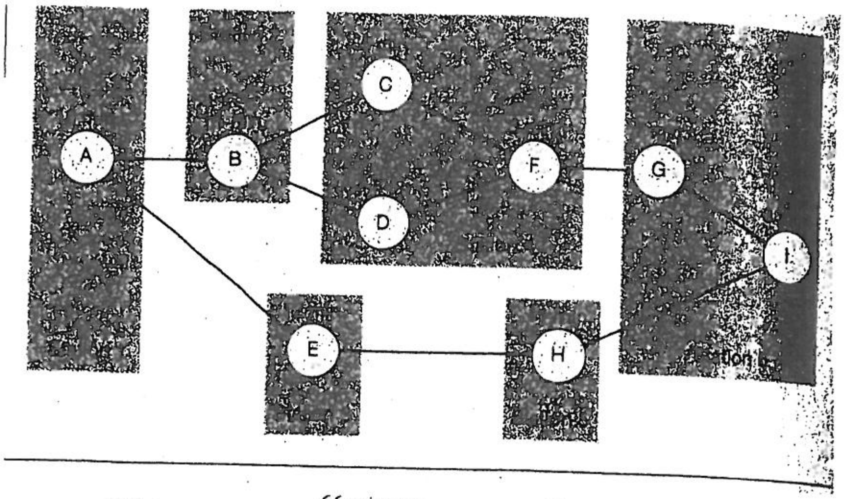


$$\text{Cycle time (in minutes)} = \frac{480 \text{ minutes}}{40 \text{ units}}$$

$$= 12 \text{ minutes/unit}$$

$$\text{Minimum number of workstations} = \frac{\text{total task time}}{\text{cycle time}} = \frac{66}{12}$$

$$= 5.5 \text{ or } 6 \text{ stations}$$

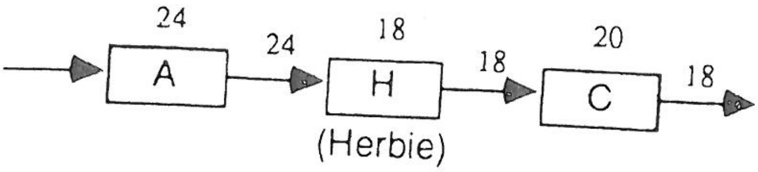


$$\text{Efficiency} = \frac{66 \text{ minutes}}{(6 \text{ stations}) \times (12 \text{ minutes})} = \frac{66}{72} = 91.7\%$$

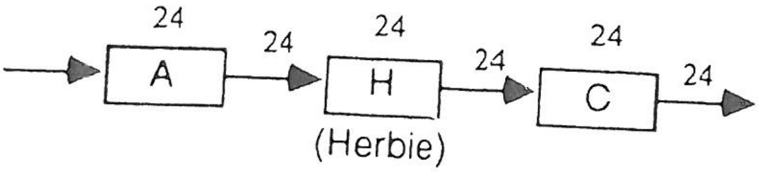
Note that opening a seventh workstation, for whatever reason, would decrease the efficiency of the balance to 78.6%:

$$\text{Efficiency} = \frac{66 \text{ minutes}}{(7 \text{ stations}) \times (12 \text{ minutes})} = 78.6\%$$

12a. The effective capacity of the system is limited by the bottleneck operation, H, to 18 units per day. If operation A produces 24 units per day, a large WIP inventory will build in front of operation H, but throughput will still be limited to 18 units per day.



With overtime, the daily capacities are:

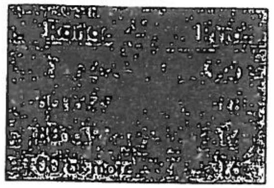


We would expect the throughput to increase to 24 units per day. However, the output increased to only 21 units per day. Possible causes include 1) fatigue from overtime, 2) material shortages, and 3) the loss of throughput that always occurs when variable operations are closely linked. The output rates are *average rates*, meaning that at any particular time the production rate at one of the operations could be less than the 24 units per day rate and cause a temporary bottleneck. When the operations are closely linked, (no WIP) throughput is always determined by the (momentary) weakest link. The system can not take advantage of favorable conditions at one operation unless those favorable conditions occur simultaneously at all operations. The upshot of all this is that the average throughput of closely linked operations will almost always be less than would be expected from just looking at average capacities. For a thorough discussion of bottlenecks, see *The Goal*, by Eli Goldratt.

13. The maintenance department of a large hospital uses about 816 cases of liquid cleanser annually. Ordering costs are $12, carrying costs are $4 per case a year, and the new price schedule indicates that orders of less than 50 cases will cost $20 per case, 50 to 79 cases will cost $18 per case, 80 to 99 cases will cost $17 per case, and larger orders will cost $16 per case. Determine the optimal order quantity and the total cost.

See Figure 13–10.

D = 816 cases per year S = $12 H = $4 per case per year



1. Compute the common EOQ: $= \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(816)12}{4}} = 70$ cases

2. The 70 cases can be bought at $18 per case because 70 falls in the range of 50 to 79 cases. The total cost to purchase 816 cases a year, at the rate of 70 cases per order, will be

$$TC_{70} = \text{Carrying cost} + \text{Order cost} + \text{Purchase cost}$$
$$= (Q/2)H + (D/Q_0)S + PD$$
$$= (70/2)4 + (816/70)12 + 18(816) = \$14{,}968$$

Because lower cost ranges exist, each must be checked against the minimum cost generated by 70 cases at $18 each. In order to buy at $17 per case, at least 80 cases must be purchased. (Because the TC curve is rising, 80 cases will have the lowest TC for that curve's feasible region.) The total cost at 70 cases will be

$$TC_{80} = (80/2)4 + (816/80)12 + 17(816) = \$14{,}154$$

To obtain a cost of $16 per case, at least 100 cases per order are required, and the total cost will be

$$TC_{100} = (100/2)4 + (816/100)12 + 16(816) = \$13{,}354$$

Therefore, because 100 cases per order yields the lowest total cost, 100 cases is the overall optimal order quantity.

Product Characteristics

Logistics costs are sensitive to such characteristics as product ***weight***, ***volume*** (cube), ***value***, and ***risk***.
In the logistics channel, these characteristics can be altered through package design or finished state of the product during shipment and storage. For example, shipping a product in a knocked-down form can considerably affect the weight-bulk ratio of the product and the associated transportation and storage costs.

A firm producing high valued goods (such as machine tools and computers) with logistics costs being a fraction of total costs will likely give little attention to the optimality of logistics strategy.
However, when logistics costs are high, as they can be in the case of packaged industrial chemicals and food products, logistics strategy is a key concern.

14- a Classifying Products

Consumer Products are those that are directed to ultimate consumers.
A three-fold consumer classification has been suggested

Convenience Products are those goods and services that consumers purchase frequently, immediately, and with limited comparative shopping. Typical products are banking services, tobacco items, and many foodstuffs.
These products generally require wide distribution through many outlets. Distribution costs are typically high but more than justified by the increased sales potential that is brought about by this wide and extensive distribution.
Customer service levels are expressed in terms of product availability and accessibility. (Examples are vending machines for Pepsi-cola etc., and telephone kiosks all over the place).

Shopping Products are those for which customers are willing to seek and compare: shopping many locations, comparing price and quality, performance, and making a purchase only after careful deliberation. Typical products in this category are fashion clothes, automobiles, and home furnishings.
Because of the customer's willingness to shop around, the number of stocking points is substantially reduced as compared with convenience goods and services. Distribution costs for such suppliers are somewhat lower than convenience goods.

Specialty Products are those for which buyers are willing to expend a substantial effort and often to wait a significant amount of time in order to require them. Buyers seek out particular types and brands of goods and services. Examples can be almost any type of good ranging from fine foods to custom made automobiles or a service such as management consultancy advice. Because buyers insist on particular brands, distribution is centralized and customer service levels are not as high as for convenience and shopping products. Physical distribution costs can be the lowest of any product category. Because of this, many firms will attempt to create a brand preference for their product line.

Industrial Products are those that are directed to individuals or organizations that use them to produce other goods or services. Their classification is quite different from consumer products.

Traditionally, industrial goods and services have been classified according to the extent to which they enter the production process. For example, there are goods that are part of the finished product, such as raw materials and component parts; there are goods that are used in the manufacturing process, such as buildings and equipment; and there are goods that do not enter the process directly, such as supplies and business services. Although this classification is valuable in preparing a selling strategy, it is not clear if it is useful in planning a physical distribution strategy.

Industrial buyers do not seem to show preferences for different service levels for different product classes. This simply means that traditional product classification for industrial products may not be useful for identifying typical logistics channels, as is the classification of consumer products.

The Product Life Cycle

Products do not generate their maximum sales volume immediately after being introduced, nor do they maintain their peak sales volume indefinitely. The physical distribution strategy differs for each stage. During the introductory stage, the strategy is a cautious one, with stocking restricted to relatively few locations. Product availability is limited.

If the product receives market acceptance, sales are likely to increase rapidly. Physical distribution is particularly difficult at this stage. Often there is not much of a sales history that can guide inventory levels at stocking points or even the number of stocking points to use.

The growth stage may be fairly short, followed by a longer stage called maturity. Sales growth is slow or stabilized at a peak level. The product volume is no longer undergoing rapid change, and therefore can be assimilated into the distribution pattern of similar existing products. At this time the product has its widest distribution. Many stocking points are used with good control over product availability throughout the market place.

Eventually the sales volume declines for most products as a result of technological change, competition, or waning consumer interest. To maintain efficient distribution, patterns of product movement and inventory deployment have to be adjusted. The number of stocking points is likely to be decreased and the product stocking reduced to fewer, and more centralized location.

The 80 –20 Curve

The product line of a typical firm is made up of individual products at different stages of their respective life cycles and with different degrees of sales success. At any point in time, this creates a product phenomenon known as the 80- 20 curve.

The bulk of the sales are generated from relatively few products in the product line and from the principle known as Pareto´s law. That is, 80 percent of a firm's sales are generated by 20 percent of the product line items. Each category of items could be distributed differently. For example, A items might receive wide geographical distribution through many warehouses and high levels of stock availability, where C items might be distributed from a single stocking point (e.g. the plant) with lower total stocking levels than for A items. B items would have an intermediate distribution strategy where a few regional warehouses are used.

14.b. Product Characteristics

The most important characteristics of the product that can influence logistics strategy are the attributes of the product itself – weight, volume, value, perishability, flammability, and substitutability. When observed in various combinations, they are an indication of the need for warehousing, inventories, materials handling, and order processing.

Weight–Bulk Ratio The ratio of weight to bulk (volume) is a particularly meaningful measure, as transportation and storage costs are directly related to them. Products that are dense, i.e. have a high weight-bulk ratio (rolled steel, printed materials, and canned foods) show good utilization of transportation equipment and storage facilities, with the costs of both tending to be low. However, for products with low density (inflated beach balls, boats, potato chips, and lamp shades), the bulk capacity of transportation equipment is not fully realized before the weight-carrying limit is reached. Also the handling and space costs, which are weight-based, tend to be high relative to the product's sales price.

Value-Weight Ratio Storage costs are particularly sensitive to value. When value is expressed as a ratio to weight, some of the obvious cost trade-offs emerge that are useful in planning the logistics system.

Products that have low value-weight ratios (coal ore, and sand) have low storage costs but high movement costs as a percentage of their sales price.
Inventory carrying costs are computed as a percentage of the product's value. Low product value means low storage cost because inventory-carrying cost is the dominant factor in storage cost.
Transportation costs on the other hand, are pegged to weight. When the value of the product is low, transportation costs represent a high proportion of the sales value.

High value- weight ratio products (electronic equipment, jewelry, and musical instruments) show the opposite pattern with higher storage and lower transport costs. If the product has a high value-weight ratio, minimize the amount of inventory maintained is a typical reaction.

Risk Characteristics Product risk characteristics refer to such patterns as perishability, flammability, value, tendency to explode, and ease of being stolen. When a product shows high risk in one or more of these features, it simply forces more restrictions on the distribution system. Both transport and storage costs are higher in absolute dollars and as a percentage of the sales price.

Logistics Customer Service

Customers view the offerings of any company in terms of price, quality, and service, and they respond with their patronage.