

## Managing Service Inventory

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- Reasons to Hold Inventory
- Single Period Inventory Decisions
- What Products do You Stock
- Surplus Stock

### What is Inventory?

A stock of materials used to satisfy customer demand or to support the production of services or goods. 銷售的商品以及維持服務所需的物料

### What is Inventory Management?

Managing the facilitating goods component of a service package involves cost tradeoffs, customer service, and information systems.

When should an order be placed? 時機

What should be the order quantity? 數量

Demand Uncertainty: How much safety stock? 安全庫存

## Who Cares About a Surplus?

In North America, the loss from overstocks in the region is estimated to cost retailers \$123.4 billion annually  
賣場庫存管理不當的損失

In Taiwan, convenience stores and supermarkets reportedly throw away 36,000 tons of food every year. The loss is at least 3.8 billion NT dollars.  
超商與超市的食物過期損失



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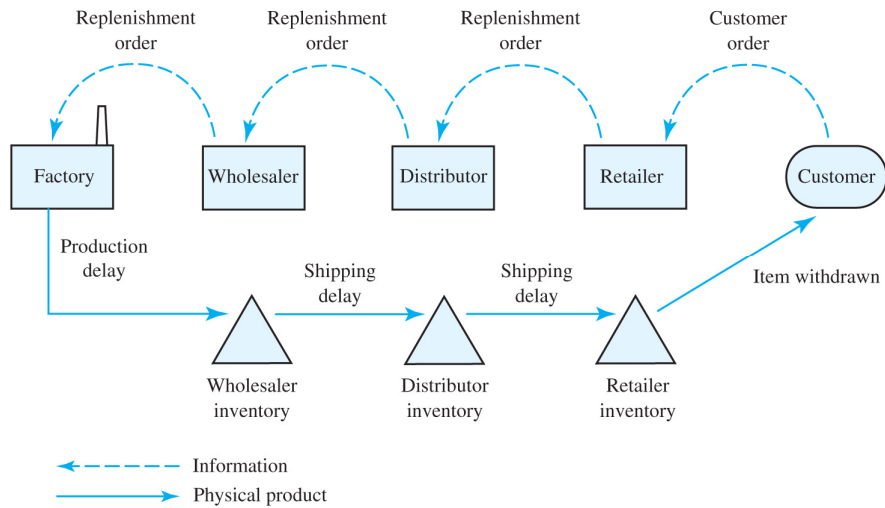
## What About a Shortage?



In 2006, Nintendo launched the Wii game console and could not make enough units to keep up with the demand. Some people would wait in long lines to purchase scarce units and resell them online for several hundred dollars over the retail price  
轉賣獲利

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## Flow of Inventory

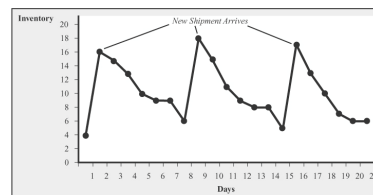


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## Reasons to Hold Inventory



- In-transit Inventory 在途
- Decoupling Inventory/Buffers 降低依賴
- Cycle Inventory 定期進貨
- Seasonal Inventory 季節性
- Safety Inventory 安全庫存
- Speculative Inventory 囤積



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## Reasons to Hold Less Inventory

- Inventory might become obsolete. 過時
- Inventory might perish. 過期
- Inventory might be stolen. 失竊
- Inventory requires storage space and other overhead cost. 儲存與管理
- Opportunity cost. 資金積壓



Inventory.  
The longer it sits, the harder it is to move.

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## Characteristics of Inventory Control

環境變數：Demand pattern 需求變化, planning horizon 規劃時間範圍, replenishment lead time 補貨時間, service constraints 服務要求

- Holding or Carrying cost ←—— order too much or too early  
storage cost: facility, handling  
risk cost: depreciation, pilferage, insurance  
opportunity cost
- Ordering cost ←—— order too little or too often  
cost placing an order: preparing, negotiating, receiving and inspection
- Shortage costs or Lost Sales ←—— order too little or too late  
costs of canceling an order or penalty

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## Inventory Control Decisions

When to order?

Reorder point, order frequency

How many to order?

Order quantity, target inventory level



Periodic Review  
Fixed Order Period



Continuous Review  
Fixed Order Quantity

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## Inventory Performance

- Holding Cost 持有成本 (inventory on hand + in transit inventory)
- Inventory turn 庫存周轉率 =  $\frac{\text{Cost of Goods Sold}}{\text{average inventory value}}$
- Service level 不缺貨水準 = in-stock probability before the replenishment order arrives
- Fill rate 供貨比例 =  $\frac{\text{number of sales}}{\text{number of demands}}$

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## Single Period Inventory Decision

- Only one procurement opportunity.
- Stochastic demand leads to lost sales or leftover.
- Order too little: losses of profit and goodwill for each unsatisfied customer. 進貨少的銷售損失
- Order too much: low salvage value for each unit of leftover. 賣不完的損失
- Forecasting helps balancing cost of ordering too much vs. cost of ordering too little. 需要預測



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## News Vendor Problem

D = boxes of donuts demanded

P = price of one box of donuts, \$10

S = salvage value of one box, \$2

Q = boxes of donuts stocked

C = cost of one box of donuts, \$4

D	Frequency	$p(D)$	Q	$P(D < Q)$
2	1	.028	2	.000
3	2	.055	3	.028
4	3	.083	4	.083
5	4	.111	5	.166
6	5	.139	6	.277
7	6	.167	7	.416
8	5	.139	8	.583
9	4	.111	9	.722
10	3	.083	10	.838
11	2	.055	11	.916
12	1	.028	12	.971

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P = price of one box, \$10 C = cost of one box, \$4 S = salvage value, \$2  
 $C_u$  = unit contribution: P-C = \$6  $C_o$  = unit loss: C-S = \$2

		Stock Q					
	$p(D)$	$D$	6	7	8	9	10
0.028	.028	2	4	2	0	-2	-4
0.083	.055	3	12	10	8	6	4
0.166	.083	4	20	18	16	14	12
0.277	.111	5	28	26	24	22	20
0.416	.139	6	36	34	32	30	28
0.583	.167	7	36	42	40	38	36
0.722	.139	8	36	42	48	46	44
0.833	.111	9	36	42	48	54	52
0.916	.083	10	36	42	48	54	60
0.971	.055	11	36	42	48	54	60
	.028	12	36	42	48	54	60
Expected profit:			\$31.54	\$34.43	\$35.77	\$35.99	\$35.33

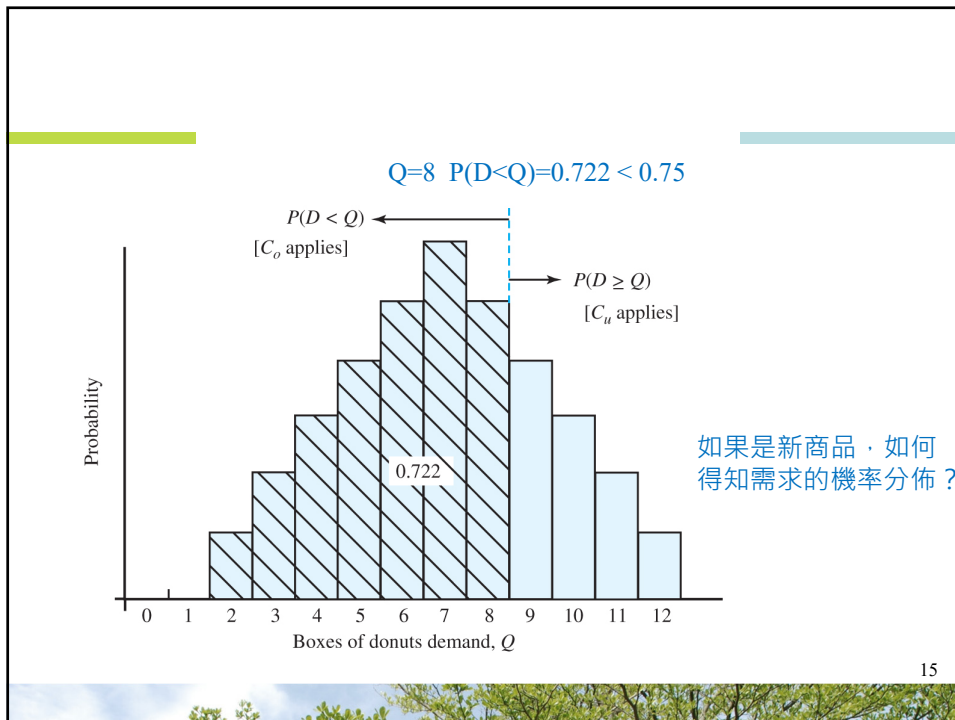
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## Finding Optimal Order Quantity

- $F(Q)$  = probability of having leftover inventory 賣不完的機率
- To maximize expected profit, we order  $Q$  units so that the expected loss on the  $Q_{th}$  unit equals the expected gain on the  $Q_{th}$  unit:  

$$C_o \times F(Q) = C_u \times (1 - F(Q))$$
 預期損失 = 預期利潤
- Rearrange the above equation  $\rightarrow F(Q) = \frac{C_u}{C_o + C_u} = 0.75$
- $C_u / (C_o + C_u)$  is called **the critical ratio**.
- Choose  $Q$  such that the probability of no lost sales (i.e., demand  $< Q$ ) equals the critical ratio.

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## Case: Ordering Decisions for Fashion Products

- Production in Asia requires a three-month lead time.
- Ordering quantity based on past sales of similar products and human judgment.
- Half of the actual demands deviate from initial forecasts by **at least 25%**. 半數品項的預測誤差大





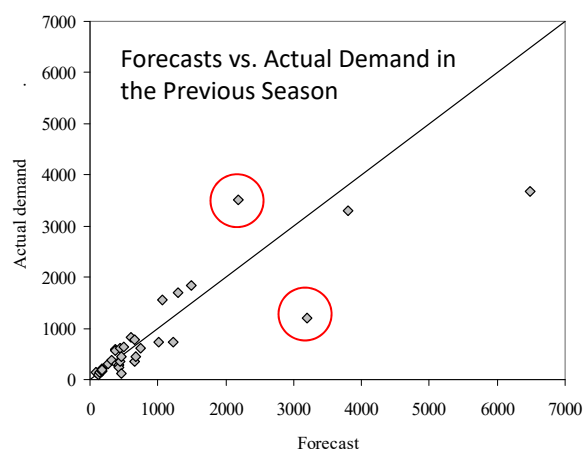
## How Reliable are Our Forecast?

- Purchasing department surveyed individuals in the organization and took the **average** as the initial forecast.
- Need more than just a number Q. Must have a sense of how accurate the forecast is. 評估預測的準確度
- Need to estimate the demand uncertainty in order to calculate  $F(Q)=\text{Prob}\{\text{Demand} \leq Q\}$

	Q	P(Q)	F(Q)
	2200	0.10	0.10
Forecast for	2800	0.20	0.30
<u>Hammer=3200</u>	3200	0.40	0.70
	3600	0.15	0.85
	4000	0.10	0.95
	4200	0.05	1.00

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## How to Estimate Demand Uncertainty?



Assume forecasting errors are caused by demand variability.  
以去年品項的預測與實際需求來估計市場需求的變化幅度

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## Forecasts vs. Actual Demand (Previous Season)

- Relative forecast errors can be measured as  $A/F \text{ ratio} = \frac{\text{actual demand}}{\text{forecast}}$

Product description	Forecast	Actual demand	Error*	A/F Ratio**
JR ZEN FL 3/2	90	140	-50	1.56
EPIC 5/3 W/HD	120	83	37	0.69
JR ZEN 3/2	140	143	-3	1.02
WMS ZEN-ZIP 4/3	170	163	7	0.96
HEATWAVE 3/2	170	212	-42	1.25
JR EPIC 3/2	180	175	5	0.97
WMS ZEN 3/2	180	195	-15	1.08
ZEN-ZIP 5/4/3 W/HOOD	270	317	-47	1.17
WMS EPIC 5/3 W/HD	320	369	-49	1.15
EVO 3/2	380	587	-207	1.54
JR EPIC 4/3	380	571	-191	1.50
WMS EPIC 2MM FULL	390	311	79	0.80
HEATWAVE 4/3	430	274	156	0.64

average A/F ratio ≈ 1 代表去年的預測沒有整體偏差

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## Sorted A/F Ratios

- Forecast errors (demand variability) in the last season maybe comparable to the current season. 設今年的市場不確定性與去年相同
- 33 products in the previous season. Minimal A/F ratio=0.25
- 3% chance that the demand is only 25% of the forecast.

Product description	Forecast	Actual demand	A/F Ratio*	Rank	Percentile**
ZEN-ZIP 2MM FULL	470	116	0.25	1	3.0%
ZEN 3/2	3190	1195	0.37	2	6.1%
ZEN 4/3	430	239	0.56	3	9.1%
WMS ELITE 3/2	650	364	0.56	4	12.1%
WMS EPIC 4/3	1060	1552	1.46	29	87.9%
JR EPIC 4/3	380	571	1.50	30	90.9%
EVO 3/2	380	587	1.54	31	93.9%
JR ZEN FL 3/2	90	140	1.56	32	97.0%
EPIC 3/2	2190	3504	1.60	33	100.0%

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## Using A/F Ratios to Estimate Distribution

Initial forecast=3200. 以去年預測的 A/F ratios 來估計新商品實際需求的變化

A/F Ratio	Q	F(Q)	A/F Ratio	Q	F(Q)	A/F Ratio	Q	F(Q)
0.25	800	0.0303	0.81	2592	0.3636	1.23	3936	0.6970
0.37	1184	0.0606	0.82	2624	0.3939	1.25	4000	0.7273
0.56	1792	0.0909	0.86	2752	0.4242	1.27	4064	0.7576
0.56	1792	0.1212	0.96	3072	0.4545	1.30	4160	0.7879
0.57	1824	0.1515	0.97	3104	0.4848	1.36	4352	0.8182
0.59	1888	0.1818	0.98	3136	0.5152	1.42	4544	0.8485
0.64	2048	0.2121	1.02	3264	0.5455	1.46	4672	0.8788
0.67	2144	0.2424	1.08	3456	0.5758	1.50	4800	0.9091
0.69	2208	0.2727	1.15	3680	0.6061	1.54	4928	0.9394
0.72	2304	0.3030	1.17	3744	0.6364	1.56	4992	0.9697
0.80	2560	0.3333	1.19	3808	0.6667	1.60	5120	1.0000

3% chance that the demand is no more than 800. 有可能不超過800

9.1% chance that the demand is at least 4800. 有可能超過4800

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## “Too much” and “Too little” Costs

- 售價  $p = 180$ ; 進貨成本  $c = 110$ ; 出清價格  $v = 90$
- $C_o$  = overage cost, cost of ordering one more unit than what you would have ordered **had you known demand**.

For the Hammer 3/2 進貨太多賣不完

$$C_o = \text{cost} - \text{salvage value} = c - v = 110 - 90 = 20$$

- $C_u$  = underage cost, cost of ordering one fewer unit than what you would have ordered **had you known demand**.

For the Hammer 3/2 進貨太少不夠賣

$$C_u = \text{price} - \text{cost} = p - c = 180 - 110 = 70$$

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## Hammer 3/2's Optimal Order Quantity

- Inputs:  $C_u = 180 - 110 = 70$ ;  $C_o = 110 - 90 = 20$
- Evaluate the critical ratio:  $\frac{C_u}{C_o + C_u} = \frac{70}{20 + 70} = 0.7778$
- Lookup 0.7778 in the empirical distribution table

Product description	Forecast	Actual demand	A/F Ratio	Rank	Percentile
⋮	⋮	⋮	⋮	⋮	⋮
HEATWAVE 3/2	170	212	1.25	24	72.7%
HEAT 3/2	500	635	1.27	25	75.8%
HAMMER 3/2	1300	1696	1.30	26	78.8%
⋮	⋮	⋮	⋮	⋮	⋮

- Convert A/F ratio into the order quantity  

$$Q = \text{Forecast} * A / F = 3200 * 1.3 = 4160.$$

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## Surplus Stocks

- There are various reasons for surplus stocks.

Over ordering 進貨過多, obsolescence 商品過時, fall in demand 銷售不佳, inaccurate stock records 盤點錯誤, stocks being returned 大量退貨

- Solutions

Retention with reduction of any further orders. 減少後續訂單

Offer discount to other users. 降價出清

Sale as scrap or for recycling. 資源回收

Disposal as waste. 當成垃圾清運

## Retail Discounting Model

- S = current selling price
- D = discount price
- P = profit margin on cost (% markup as decimal)
- Y = average number of years to sell entire stock of “dogs” at current price (total years to clear stock divided by 2)
- N = inventory turns (number of times stock turns in one year)

Loss per item = Gain from revenue

$$S - D = D(P \times N \times Y) \Rightarrow D = \frac{S}{(1 + P \times N \times Y)}$$

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## Case: What Products Should You Stock?

	National HIGH	National MEDIUM	House 1 HIGH	House 2 HIGH	House 2 MEDIUM	House 3 LOW	Total units sold
A	100			29	28	190	347
B	282	21		30	203		536
C				11	12	86	109
D				53	50	284	387
E	72	64	20	172	570		898
F	59		97	285	763		1,204
G	10		16	14	76		116
H		7	33	157	377		574
I		10		183	524		717
J		39		225	568		832
K			8	10	73		91
L			8	47	223		278
M				43	298		341
N				72	221		293
O	8					200	208
Total units sold	531	141	182	1,331	3,986	760	6,931
Share of total sales	7.7%	2.0%	2.6%	19.2%	57.5%	11.0%	

銷售空間有限，無法提供各品牌所有規格

找出dogs不難，找到替換的商品才是重點

## 估算各規格的最大需求

$$1204 \div (7.7\% + 2.6\% + 19.2\% + 57.5\%) = 1384$$

	National HIGH	National MEDIUM	House 1 HIGH	House 2 HIGH	House 2 MEDIUM	House 3 LOW	Total units sold	Share of demand captured	Total demand
A	100			29	28	190	347	95.3%	364
B	282	21		30	203		536	86.4	620
C				11	12	86	109	87.7	124
D				53	50	284	387	87.7	441
E	72	64	20	172	570		898	89.0	1,009
F	59		97	285	763		1,204	87.0	1,384
G	10		16	14	76		116	87.0	133
H		7	33	157	377		574	81.4	705
I		10		183	524		717	78.8	910
J		39		225	568		832	78.8	1,056
K			8	10	73		91	79.4	115
L			8	47	223		278	79.4	350
M				43	298		341	76.7	444
N				72	221		293	76.7	382
O	8					200	208	18.6	1,119
Total units sold	531	141	182	1,331	3,986	760	6,931		
Share of total sales	7.7%	2.0%	2.6%	19.2%	57.5%	11.0%			
								1384 × 57.5% = 796	

## 修正品牌市占率：顧客被迫接受第二選擇

	National HIGH	National MEDIUM	House 1 HIGH	House 2 HIGH	House 2 MEDIUM	House 3 LOW	Total units sold	Share of demand captured	Total demand
A	100			29	28	190	347	97.3%	357
B	282	21		30	203		536	28.8	1,862
C				11	12	86	109	94.9	115
D				53	50	284	387	94.9	408
E	72	64	20	172	570		898	30.3	2,960
F	59		97	285	763		1,204	29.2	4,123
G	10		16	14	76		116	29.2	397
H		7	33	157	377		574	27.9	2,054
I		10		183	524		717	26.4	2,717
J		39		225	568		832	26.4	3,153
K			8	10	73		91	26.8	339
L			8	47	223		278	26.8	1,037
M				43	298		341	25.3	1,350
N				72	221		293	25.3	1,160
O	8					200	208	72.0	289
Total units sold	531	141	182	1,331	3,986	760	6,931		
Share of total sales	7.7%	2.0%	2.6%	19.2%	57.5%	11.0%			
Best-fit demand shares	2.4%	1.1%	1.5%	6.7%	18.6%	69.6%		4123 × 69.6% = 2869	

$$1204 \div (2.4\% + 1.5\% + 6.7\% + 18.6\%) = 1204 \div 29.2\% = 4123 \Rightarrow 4123 \times 18.6\% = 767$$

## 預測引進新規格的銷售量

	National HIGH	National MEDIUM	House 1 HIGH	House 2 HIGH	House 2 MEDIUM	House 3 LOW
A		4	6			
B			29			1,297
C	3	1	2			
D	10	5	6			
E						2,060
F		46				2,862
G		4				276
H	49					1,430
I	65		43			1,892
J	75		50			2,196
K	8	4				236
L	25	12				721
M	32	15	21			940
N	28	13	18			808
O		3	5	19	54	

- ✓ 現有銷售量無法顯現真實的市場需求
- ✓ 顧客可能不接受第二選擇，可能不介意第二選擇

## Summary

- Good inventory management is characterized by concern for holding costs, ordering costs, shortage costs, and the purchase price. 平衡各項成本
- Consider demand uncertainty. 進貨決策應考慮需求的變化
- The optimal order quantity for fashion items depends on the salvage value and the cost of lost sales. 考慮流行商品的殘值

