Chapter 15. Assemble-to-Order, Make-to-Order, and Quick Response with Reactive Capacity

Make-to-Stock vs. Make-to-Order

- Make-to-Stock: commit to its entire supply before demand occurs
- Make-to-Order (Assemble-to-Order): begin producing an item only when it receives a firm order from a customer (e.g. Dell)
- Between two modes: submit a 2nd order that is received well before the end of the season
- Quick Response: capability to place multiple orders during a selling season
- Reactive Capacity: capacity that allows a firm to place one additional order

ELSEVIER

Int. J. Production Economics 48 (1997) 21–28

international journal of production economics

Distribution free procedures for make-to-order (MTO), make-in-advance (MIA), and composite policies

Ilkyeong Moon*, Sangjin Choi

Department of Industrial Engineering, Pusan National University, Pusan 609-735, South Korea

The demand-supply mismatch cost

- Definition – the ***demand supply mismatch cost*** includes the cost of left over inventory ("too much" cost) plus the opportunity cost of lost sales ("too little" cost):

$$Mismatch\ cost = \left(C_o \times Expected\ left\ over\ inventory\right) + \left(C_u \times Expected\ lost\ sales\right)$$

  - For Hammer 3/2:
- Selling Price=$190, Purchase Price from TEC =$110
- Discount Price at the end of the season (Salvage Value) =$90

$$\text{Mismatch cost} = (\$20 \times 1134) + (\$80 \times 130) = \$33{,}080$$

The demand-supply mismatch cost

- The ***maximum profit*** is the profit without any mismatch costs, i.e., every unit is sold and there are no lost sales:

$$Maximum\ profit = (p - c) \times \mu$$

- The mismatch cost can also be evaluated with
  - For the Hammer 3/2:

Mismatch cost = Maximum profit – Expected profit

$$Maximum\ profit = (\$190 - \$110) \times 3192 = \$255{,}360$$

$$\text{Mismatch cost} = \$255{,}360 - \$222{,}280 = \$33{,}080$$

Mismatch costs as % of the maximum profit …

- The mismatch cost is high when the **coefficient of variation, $\frac{\sigma}{\mu}$, is high and the critical ratio is low**: click.

$$\left(\frac{\phi(z)}{\Phi(z)}\right)\times\left(\frac{\sigma}{\mu}\right)$$

Coefficient of variation	Critical ratio 0.4	0.5	0.6	0.7	0.8	0.9
0.10	10%	8%	6%	5%	3%	2%
0.25	24%	20%	16%	12%	9%	5%
0.40	39%	32%	26%	20%	14%	8%
0.55	53%	44%	35%	27%	19%	11%
0.70	68%	56%	45%	35%	24%	14%
0.85	82%	68%	55%	42%	30%	17%
1.00	97%	80%	64%	50%	35%	19%

Appendix D (p477)

- **Mismatch cost as a % of the maximum profit**

$$Mismatch\ cost = (C_o \times Expected\ left\ over\ inventory) + (C_u \times Expected\ lost\ sales)$$

$$Maximum\ profit = (p - c) \times \mu$$

$$\text{Mismatch cost as a \% of the maximum profit} = (C_o \times \text{Expected leftover inventory})/(\mu \times C_u) + (C_u \times \text{Expected lost sales}) / (\mu \times C_u) \qquad (*)$$

$$\text{Expected leftover inventory} = (Q - \text{Expected sales}) = (Q - \mu + \text{Expected lost sales})$$

$$Q = \mu + z \times \sigma \Rightarrow z \times \sigma = (Q - \mu)$$

(*)에 대입

Appendix D (p477)

- **Mismatch cost as a % of the maximum profit**

$$\frac{\text{Mismatch cost as a \% of the}}{\text{maximum profit}} = ((C_o \times z \times \sigma) + (C_o + C_u) \times \text{Expected lost sales})/(\mu \times C_u \qquad (**)$$

$$\text{Expected lost sales} = \sigma \times (\phi(z) - z \times (1 - \Phi(z)))$$

$$= \sigma \times \left(\phi(z) - z \times \frac{C_o}{C_o + C_u}\right)$$

(**)에 대입

$$\frac{\text{Mismatch cost as a \% of the}}{\text{maximum profit}} = \left(\frac{\phi(z)}{\Phi(z)}\right) \times \left(\frac{\sigma}{\mu}\right)$$

critical ratio coefficient of variation

Appendix D (p477)

- **Mismatch cost as a % of the maximum profit**

$$\text{Let } f(z) = \frac{\phi(z)}{\Phi(z)}$$

$$f'(z) = \frac{\phi(z)(-z)\Phi(z) - \{\phi(z)\}^2}{\{\Phi(z)\}^2}$$

$$= \frac{-\phi(z)\{z\Phi(z) + \phi(z)\}}{\{\Phi(z)\}^2}$$

$$-\phi(z)\{z\Phi(z) + \phi(z)\} \le 0 \; as \; z \ge 0$$

$$\therefore f(z) \; is \; a \; decreasing \; function$$

If critical ratio increases, $\frac{\phi(z)}{\Phi(z)}$ decreases.

Reducing mismatch cost with Make-to-Order

Pros and cons of Make-to-Order

- No leftover inventory (good for products with a high mismatch cost)
- Need to carry component inventory
- Customers must wait to have their order filled (Successful implementation of make-to-order requires fast and easy assembly of the final product)
- Make-to-Order requires some idle capacity

Successful company which implements Make-to-Order ⇒ **Dell**

- Inventory is very expensive to hold because of obsolescence and falling component prices
- Labor is a small portion of the cost of PC due to the **modular design**
- Customers are primarily concerned with price and customization (**patient**)
- Transportation cost is reasonable
- On-line channels work

Quick Response with Reactive Capacity

O'Neill Example: Make-to-Stock vs Make-to-Order

How about an intermediate solution?
Commit to some supply before demand but then maintain the option to produce additional supply after some demand is observed.

Reactive Capacity: React to demand information it learns before committing to the 2nd order

Make some simplifying assumptions that allow for analytical tractability while retaining the key qualitative features of the complex problems.

Quick Response with Reactive Capacity

O'Neill Example: 2nd order opportunity (See Figure 15.1 on p328)
TEC will charge 20% premium for the 2nd order due to the reservation of capacity.

The issue is whether the cost increases associated with the 2nd order justify the mismatch cost savings for O'Neil?

C_o = *Cost – Salvage value = c – v* = 110 – 90 = 20
C_u = *Additional premium we must pay to TEC for units in the 2nd order*
= 20% X 110 = 22

critical ratio= $$\frac{C_u}{C_o + C_u} = \frac{22}{20+22} = 0.5238 \Rightarrow z = 0.06$$

$$Q = \mu + z \times \sigma$$
$$= 3192 + 0.06 \times 1181 = 3263$$ vs. 4196 (no 2nd order)

Quick Response with Reactive Capacity

$$
\begin{aligned}
\text{Expected Profit} &= \left[(\text{Price} - \text{Cost}) \times \mu\right] \\
&\quad - \begin{bmatrix} (\text{Cost} - \text{Salvage value}) \times \text{Expected leftover inventory} \\ (= \text{Expected leftover inventory} = \sigma \times I(z)) \end{bmatrix} \\
&\quad - \left[C_u \times \text{Expected 2nd order quantity}\right] \\
&= \$255{,}360 - \$20 \times 507 - \$22 \times 436 = \$235{,}628 \\
&\quad (vs. \$222{,}280)
\end{aligned}
$$

Profit increased by 6%

Mismatch Cost: \$255,360－\$235,628=\$19,732 (vs. \$33,080)
(40% reduction! ←unrealistic assumption?)

QR with Reactive Capacity⇒
A feasible strategy for significantly reducing mismatch cost!

Order quantity that maximizes the expected profit

- The critical ratio is $\frac{C_u}{C_o + C_u} = \frac{80}{20+80} = 0.80$

- Find the critical ratio <u>inside</u> the *Standard Normal Distribution Function Table:*

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389

  - If the critical ratio falls between two values in the table, choose the greater *z*-statistic … this is called the ***round-up rule***.
  - Choose *z* = 0.85

- Convert the z-statistic into an order quantity :

$$Q = \mu + z \times \sigma$$
$$= 3192 + 0.85 \times 1181 = 4196$$

Expected lost sales with *Q* = 4196

- Suppose O'Neill orders 4196 Hammer 3/2s.
- How many sales will be lost on average?

- To find the answer:
  - Step 1: normalize the order quantity to find its *z*-statistic.

$$z = \frac{Q - \mu}{\sigma} = \frac{4196 - 3192}{1181} = 0.85$$

  - Step 2: Look up in the *Standard Normal Loss Function Table* the expected lost sales for a standard normal distribution with that *z*-statistic: $L(0.85)=0.1100$

  - Step 3: Evaluate lost sales for the actual normal distribution:

$$\text{Expected Lost Sales} = \sigma \times L(z) = 1181 \times 0.1100 = 130$$

Measures that follow expected lost sales

If they order 4196 Hammer 3/2s, then …

Expected sales = μ - Expected lost sales = 3192 – 130 = 3062

Expected left over Inventory = Q - Expected sales = 4196 – 3062 = 1134

$$
\begin{aligned}
\text{Expected Profit} &= \left[\left(\text{Price - Cost} \right) \times \text{Expected sales} \right] \\
&\quad - \left[\left(\text{Cost - Salvage value} \right) \times \text{Expected left over inventory} \right] \\
&= \$80 \times 3062 - \$20 \times 1134 \\
&= \$222{,}280
\end{aligned}
$$

Mismatch costs when critical ratio is high

high critical ratio ⇒ large profit margin

(relative to the loss on each unit of excess inventory)

⇒ optimal order quantity is quite large (eg. Christmas card)

⇒ few lost sales & large amount of leftover inventory (cost ↓)

⇒ the total mismatch cost is small

Modular Design

An approach (design theory and practice) that subdivides a system into smaller parts called modules that can be independently created and then used in different systems

Modular Design