APPENDIX 16A

The Beer Game

The Beer Game originated at MIT and has been used to simulate the performance of a simple supply chain with one player at each stage. The game is often used to illustrate the bullwhip effect in a simple supply chain. The supply chain consists of a manufacturer, a distributor, a wholesaler, and a retailer as shown in Figure 16.6.

Customers come to the retailer to purchase beer. The retailer tries to fill customer orders from beer in inventory. Any unfilled demand is carried over to the future as backlogged demand. The retailer places replenishment orders with the wholesaler, who tries to fill the orders from beer in inventory. The wholesaler in turn orders from the distributor and the distributor from the manufacturer. The manufacturer receives raw materials from a supplier. It takes two periods for orders and product to move between stages. In the game, the delay is accomplished by introducing an in-transit stage between every pair of stages in the supply chain, as shown in Figure 16.6. The game is played by assigning two people to each of the four stages (retailer to manufacturer) of the supply chain. Several supply chains can operate simultaneously.

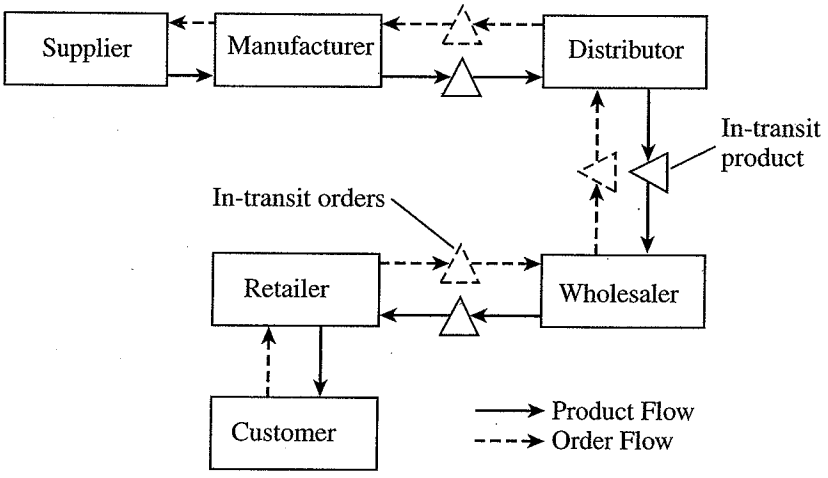
Each supply chain requires a customer board, a supplier board, four identical boards corresponding to each of the four stages, and three identical in-transit boards. The four different types of boards are shown in Figure 16.7.

The boards are ordered as in Figure 16.6 with the retailer, wholesaler, distributor, and manufacturer getting a stage board each. An in-transit board is placed between every pair of stages, resulting in three in-transit boards. The customer board is placed before the retailer, and the supplier board is placed after the manufacturer.

Each of the four stages gets a recording sheet, as shown in Table 16.3.

Current period demand is the size of the order received in this period. *Gross demand* during a period is the sum of the *current period demand* and *backlog* from the previous period. Gross demand represents the amount that a stage has to try to supply this period. *Amount shipped* is the quantity shipped during the period. Amount shipped should equal gross demand if there is sufficient inventory available. If gross demand exceeds inventory available, then the entire inventory will be shipped and

FIGURE 16.6 Beer Game Supply Chain



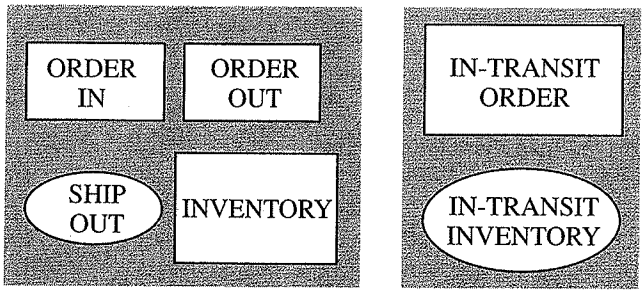


FIGURE 16.7 Boards to Be Used for Beer Game

the unfilled demand added to the backlog. *Ending inventory* measures the cases of beer in inventory right after a shipment has been sent. *Backlog* is the amount of demand that has not yet been supplied. For any period

$$\text{Backlog} = \text{previous period backlog} + \max\{0, \text{gross demand} - \text{amount shipped}\}.$$

Order placed is the amount ordered by a stage with its supplier.

A cost of \$1 is incurred for each case of beer in *ending inventory* per period. A cost of \$2 is incurred for each case of demand in *backlog* per period. The goal of each stage is to minimize the total cost incurred over the period when the game is played. The performance of a stage will be compared with the performance of the same stage in other supply chains.

During the game, orders are written on pieces of paper and pennies are used to represent cases of beer. The game starts with a sequence of orders placed in the customer order box. The game is played through multiple periods. At the start of each period, the following layout exists.

1. The ORDER-IN box at each of the four stages contains an order.

TABLE 16.3 Recording Sheet for Beer Game

Period	*Current Period Demand*	*Gross Demand*	*Amount Shipped*	*Ending Inventory*	*Backlog*	*Order Placed*
1						
2						

2. Each IN-TRANSIT ORDER box contains an order and each IN-TRANSIT INVENTORY box contains some pennies representing beer in transit.
3. The RAW-MATERIAL ORDER box contains an order.

During each period, the activities performed by each stage are divided into two phases. The game works best if one person at each stage takes responsibility for the first phase and the other person takes responsibility for the second phase. The completion of both phases completes all activities to be performed during a period. All four stages must have finished Phase I before any of them can start Phase II in a period. At the end of each period, the layout looks the way it did at the start of the period. The supply chain then moves on to the next period. We now describe the activities performed in each phase of the period at all four stages.

PHASE I ACTIVITIES (COMMON TO ALL FOUR STAGES)

The goal during this phase is to fill the incoming order and place a replenishment order. Phase I activities are identical for all four stages of the supply chain.

1. Pick order from ORDER-IN box and record on recording sheet as *Current Period Demand.*
2. Compute *Gross Demand* by adding *Current Period Demand* (from this period) and *Backlog* (from previous period).
3. Transfer the minimum of the amount in the INVENTORY box and *Gross Demand* from the INVENTORY box to the SHIP OUT box. Record the amount transferred as the *Amount Shipped.*
4. Record *Ending Inventory* as the amount remaining in the INVENTORY box.
5. Compute *Backlog* = max{*Gross Demand* – *Amount Shipped*, 0} and record on recording sheet.
6. Place a replenishment order with the supplier on an order slip and place the order slip in the ORDER-OUT box. Record *Order Placed* on the recording sheet.

PHASE II ACTIVITIES FOR RETAILER

In this phase the retailer receives orders from the customer, beer from the wholesaler, and moves beer to the customer and orders to the wholesaler.

1. Move order from IN-TRANSIT ORDER box between retailer and wholesaler to the ORDER-IN box of the wholesaler.
2. Move order from ORDER-OUT box of retailer to IN-TRANSIT ORDER box between retailer and wholesaler.
3. Move beer from IN-TRANSIT INVENTORY box between retailer and wholesaler to INVENTORY box at retailer.
4. Move beer from SHIP-OUT box of wholesaler to IN-TRANSIT INVENTORY box between retailer and wholesaler.
5. Mover order at top of pile in CUSTOMER ORDER box to ORDER-IN box of retailer.
6. Move beer from SHIP-OUT box of retailer to CUSTOMER BEER box.

PHASE II ACTIVITIES FOR WHOLESALER

In this phase, the wholesaler moves orders to the distributor and receives beer from the distributor.

1. Move order from IN-TRANSIT ORDER box between wholesaler and distributor to ORDER-IN box at distributor.
2. Move order from ORDER-OUT box at wholesaler to IN-TRANSIT ORDER box between wholesaler and distributor.
3. Move beer from IN-TRANSIT ORDER box between wholesaler and distributor to INVENTORY box at wholesaler.
4. Move beer from SHIP-OUT box at wholesaler to IN-TRANSIT ORDER box between retailer and wholesaler.

PHASE II ACTIVITIES FOR DISTRIBUTOR

In this phase, the distributor moves orders to the manufacturer and receives beer from the manufacturer.

1. Move order from IN-TRANSIT ORDER box between distributor and manufacturer to ORDER-IN box at manufacturer.
2. Move order from ORDER-OUT box at distributor to IN-TRANSIT ORDER box between distributor and manufacturer.
3. Move beer from IN-TRANSIT ORDER box between distributor and manufacturer to INVENTORY box at distributor.
4. Move beer from SHIP-OUT box at distributor to IN-TRANSIT ORDER box between distributor and manufacturer.

PHASE II ACTIVITIES FOR MANUFACTURER

In this phase the manufacturer receives raw materials from the supplier and moves the next order to the supplier.

1. Take order from RAW-MATERIAL ORDER box at SUPPLIER and move equivalent amount of beer from RAW MATERIALS box at supplier to INVENTORY box at manufacturer.
2. Move order from ORDER-OUT box at manufacturer to RAW-MATERIAL ORDER box at supplier.

The game is stopped after a suitable number of periods have expired. Each stage then evaluates the total cost it has incurred and plots the orders it received. With this information, each stage should come up with a guess at what the customer demand pattern looked like for the periods that the game is played.