Managing the Cost–Service Relationship Through Backorder Control

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The backorder holds considerable promise as a supplementary measure of distribution system performance. The backorder can be viewed as the "fine-tuning" mechanism, linking distribution costs and services.

The industrial manufacturer must regularly monitor distribution system performance because of the importance of physical distribution services to purchasers [1,5,6,7]. Thus, service has become a critical competitive tool whereby suppliers can be differentiated by customers. This gives a decided advantage to the firm that understands the interrelationships among the components of its distribution network. Such a firm can provide the desired service level while maintaining the resultant costs at or near the minimum level. The cost–service functional relationship can be derived from historical data on service attainment and related distribution costs. But how does the distribution manager know if the cost-service relationship is based on minimum cost for the required service level? Ultimately, the answer comes from managerial experience and judgment; however, the consequences of management mistakes with respect to realizing minimal costs directly affects profits. If distribution costs are not minimized, expenses rise, sales remain the same, and profits decline.

Recent developments in the area of backorder control suggest that the backorder may be helpful to managers attempting to define the service-minimum cost relationship more clearly. In this sense, backorders are orders placed for out-of-stock items that must either be ordered from a replenishment center or be shipped upon completion of manufacturing. The backorder can be treated as an intervening variable between distribution system performance and costs. A specific service level, such as the delivery of goods in the proper condition to 90% of all customers within 72 hr of order placement, can be accomplished by maintaining inventories at warehouse locations to fill orders or by backordering.

This alternative is often available to companies that supply their customers on a virtually continuous basis. Fluctuations in number of percentage of backorders within an accepted range (as determined by customers) does not constitute service variance, because of the frequency of orders and deliveries. But it does affect cost levels if special deliveries or smaller order sizes must be backordered. In the short-run, the tradeoff involves the cost of backordering the inefficient transportation

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(higher per-unit or per-pound cost) versus the cost of inventory maintenance and efficient inventory replenishment shipments (lower per-unit or per-pound costs because of larger shipment quantities). A backorder–cost tradeoff could eventually be determined, within a given service constraint.

ANALYSIS

The nature of the backorder–cost relationship was investigated via simulation. Simulation is a method of experimenting with several variables without risking a company's service reputation or profits. The simulation model utilized was a modified version of long-range environmental planning simulator (LREPS), a widely-used computerized model of the total physical distribution system. A detailed description of the model can be found in Bowersox et al. [2], Helferich [3], and Marien [4].

The simulated company distributed ten products nationally through two distribution centers stocked by one manufacturing facility with on-site replenishment storage capability. Variations in percent cases backordered and variable distribution costs were achieved by altering parameters within the LREPS forecasting module [5]. The basic forecasting model applied was the simple exponential smoothing model

$$F_t = \alpha D_{t-1} + (1 - \alpha)F_{t-1},$$

where F is the forecast, D is the actual demand, t is the time period, and α is the smoothing constant (0–1 range). LREPS must forecast "actual" simulated sales so that inventory levels can be determined. As is the case with real-world forecasting models, the more accurate the forecast, the better the match at a point in time between inventory composition and demand.

Inventories were permitted to become negative (no lost sales because of stockouts). When this occurred backorders were placed for immediate shipment. So the predetermined distribution system service level (0.80 probability of 48-hr delivery within 600 mile radius of distribution centers) was maintained by backordering. Twenty-five sets of forecasting model parameters (values for α and forecasting interval) were tested, resulting in 25 combinations (see Table 1) of backorder percentage and variable distribution costs (inventory carrying, backorder transportation, and replenishment transportation costs).

As backorder percentage increased from zero to two, variable distribution costs declined substantially. Within this range there was a statistically significant ($p < 0.01$) correlation ($r = 0.889$) between costs (Y) and backorder percentage (X) of the form $Y = 0.01232 - 0.00123X$. For values of $X \geqslant 2$, no linear relationship was detected. To see if the relationship between cost and backorders was curvilinear throughout the entire range of backorder percentage, an equation of the general form $Y = a(X)^b$ was fit to the data. A statistically significant ($p < 0.01$) correlation ($r = 0.945$) was found where $\ln Y = -4.51086 - 0.07697(\ln X)$; hence, the curvilinear relationship is quite appropriate within the tested range for backorder percentage. In this study, distribution costs increase at a greater rate than improvements in backorder percentage.

For increasingly larger backorder percentages (greater than those in this study), distribution costs could rise again due to the inefficiencies of numerous small backor-

TABLE 1
Backorder Percentages and Variable Physical Distribution Costs

Cases Backordered (%)	Variable Physical Distribution Costs/lb ($)
0.325	0.011 991
0.350	0.012 170
0.425	0.012 318
0.500	0.011 552
0.525	0.011 105
0.600	0.011 418
1.100	0.010 833
1.275	0.010 854
1.275	0.010 466
1.500	0.010 743
1.525	0.010 533
2.000	0.010 088
2.000	0.010 333
2.050	0.010 345
2.150	0.010 430
2.175	0.010 363
2.350	0.010 320
2.375	0.010 187
2.825	0.010 165
2.850	0.009 860
3.125	0.010 359
3.125	0.009 962
3.575	0.009 877
3.975	0.010 197
4.200	0.010 178

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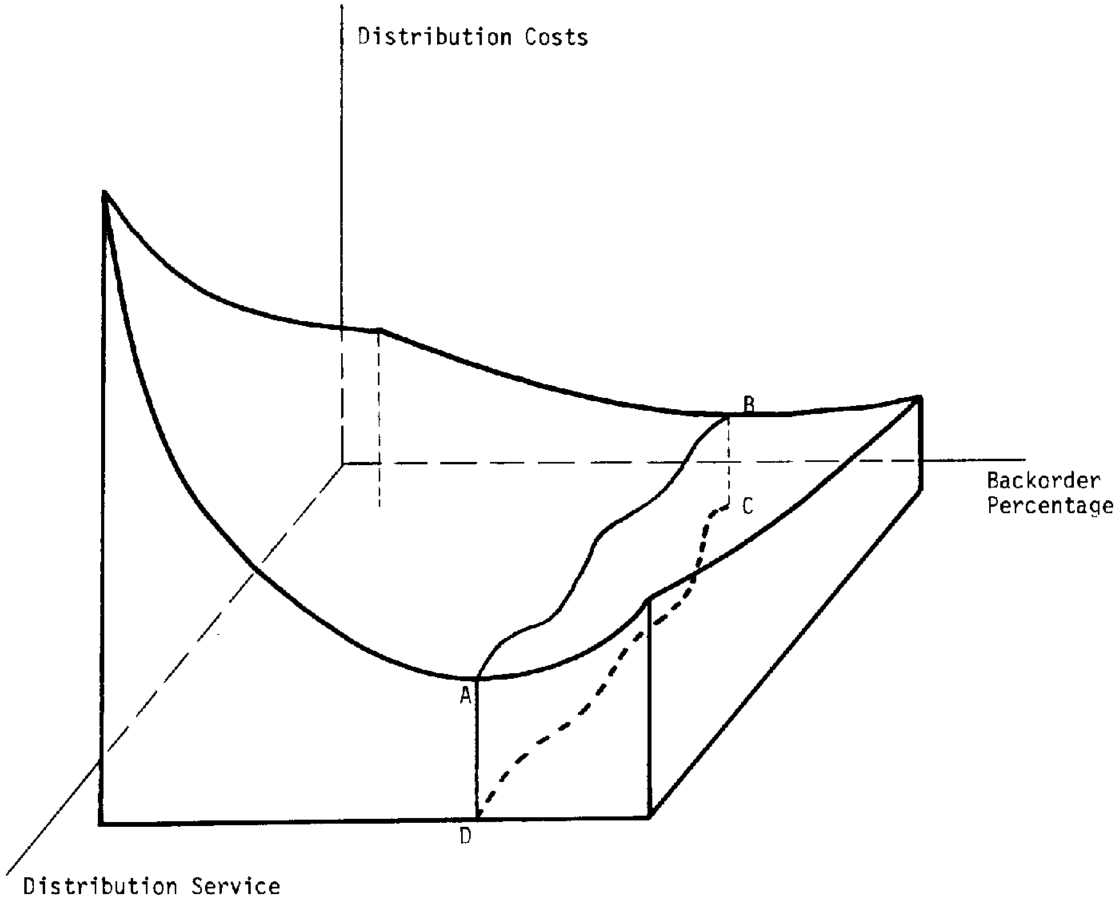

FIGURE 1. **Interrelationship among cost, service, and backorder percentage.**

der shipments. Under the assumption that Y increases eventually, a family of backorder–cost curves, one for each overall distribution system service level, can be derived (see Fig. 1). The minimum total cost line (AB in Fig. 1) can be determined by connecting the points of minimum cost for each backorder–cost relationship. By projecting this line on the backorder–service plane, a backorder–service relationship (CD in Fig. 1) is formalized, given minimum distribution costs.

This relationship can be used by the manager to improve distribution system performance. Backorder percentage within the overall service constraint becomes a surrogate measure for minimum cost.

DERIVING AND USING THE BACKORDER-COST RELATIONSHIP

Short of developing a detailed model of a company's total distribution system, there is no way to determine precisely the backorder–cost tradeoff. Workable estimates can, however, be extracted from historical data by segmenting it into, e.g., month-long time periods. For every month, backorder percentage, overall service level, and cost can be computed. Given 2 or 3 years' data, the mathematical relationship among the three variables can be approximated. By specifying the desired service, the appropriate backorder percentage can be calculated. Gradually this methodology can be improved as more data become available and management gains experience with the approach. At that point tolerance levels for acceptable backorder percentage can be administered to provide a simple indicator of system performance.

The needs of customers may have to be balanced against the optimal backorder level. If some customers will not accept backorders, as has been suggested [7], then the previous analysis may not be applicable. If a customer orders only occasionally, then today's backorder cannot be included with tomorrow's daily shipment to this customer; hence, by definition any backorders will mean a decline in service. Once again, the backorder–cost analysis may not hold.

Management must therefore determine each customer's sensitivity to different backorder levels and segment them according to service expectations. For those customers who will accept certain variations in delivery date, for whatever reasons, the foregoing procedures are quite relevant. Given the temporal and spatial service level provided to these customers, the backorder-cost relationship can be developed and analyzed to derive the optimal backorder level, which becomes an indicator of minimum cost achievement.

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