PLANNING PHYSICAL DISTRIBUTION WITH THE PRINCIPLE OF POSTPONEMENT

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HEADNOTE

The principle of postponement proposes that the time of shipment and the location of final product processing in the distribution of a product be delayed until a customer order is received. This article presents and illustrates a methodology to help managers evaluate when postponement is justified. Five types of postponement are introduced. A normative cost model is developed for each type. The impact of product physical and demand characteristics on conditions supporting postponement are then tested with computer simulation. Results show that there is a cost advantage in postponing the distribution of a substantial number of products.

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INTRODUCTION

Scrambled merchandising, product proliferation, and localized marketing have magnified the level of complexity related to physical distribution in recent years. To provide effective physical distribution support, managers need to serve an increased number of delivery destinations, while simultaneously supporting a growing number of stock keeping units.

The typical approach to resolving marketing complexity is to rely upon sophisticated forecasting techniques to predict the level of demand for each product at multiple delivery destinations, followed by anticipatory distribution in advance of actual customer demand. Moreover, to implement anticipatory physical distribution, demand must be forecasted for every brand, package size, and version in which a product is offered. Detailed forecasts are required to build inventories at the right time and place to satisfy demand. The traditional and most common optimizing models in production and physical distribution adopt such an anticipatory perspective.[1] The traditional approach to physical distribution is anticipatory.[2]

The time of shipment and the location of final product processing offer alternatives to anticipatory distribution. In time anticipation, products are shipped from plant to warehouse prior to customer demand. The product is inventoried close to the consumer to permit rapid delivery upon order receipt. In form anticipation, the final processing of products occurs at the manufacturing plant prior to warehouse shipment. The centralization of final processing has been traditionally assumed to result in lower production costs that offset the impact of forecast error. Both time and form anticipation reduce delivery time to the customer.[3]

This article presents and illustrates a methodology to help managers evaluate when postponement is justified. Postponement consists of delaying movement or final formulation of a product typically mass produced until after customer orders are received. In terms of anticipatory allocation of products to warehouses based on sales forecast, postponement advocates moving products from manufacturing plants only after customer orders are received (time postponement).[4] Knowing the exact level and location of the demand prior to product shipment offers the potential to reduce distribution cost because safety stocks can be consolidated.[5] For instance, catalog mail order firms keep inventories at a few centralized locations and only send them to customers once an order is received. It is further proposed that under specific situations the least risky procedures may be to send products to warehouses in a semi-finished state for final processing after the customer order is received (form postponement). Risk related to the uncertainty of brand, package size or model version desired by the customer is therefore reduced.[6] An example of form postponement is the addition of ice makers to refrigerators at customer request.

The opposing logics of postponement and anticipation are combined in a general principle termed postponement-speculation.[7] The principle suggests that changes in inventory location and/or in the form of a product be made at the time and/or place where it minimizes the unit cost of distribution for that product. While this principle has enjoyed long standing in the literatures of marketing and physical distribution, no substantial effort has been made to operationalize the theoretical structure in a way meaningful to managerial decision making. Thus, to provide such operationalization, the overall objectives of this article and supporting research are: (1) to propose a decision framework which enables managers to decide when postponement is justified, and (2) to provide insight based upon research analysis of specific product physical and demand characteristics that support postponement.

The article is structured into four sections. The first section introduces five types of postponement. It illustrates how each type stimulates a different set of distribution cost relationships. Five normative cost models are introduced in section two. There is one normative cost model for each type of postponement. In the third section, the results of simulating each normative cost model across a range of product physical and demand characteristics is reported. The simulation was used to test hypotheses relating product physical and demand characteristics supporting postponement. The purpose of the research was to identify characteristics to help rapidly identify products for which postponement has the potential to reduce distribution cost. In the fourth section, the conclusions and managerial implications are presented.

POSTPONEMENT TYPES

Five types of postponement were developed. Four different types of form postponement can be introduced as alternatives to anticipatory distribution: labeling, packaging, assembly, and manufacturing. These four types of form postponement, when combined with time postponement, constitute the five types.

Each type has different distribution costs. The following cost categories are considered: customer service level (cost of lost sales, processing (labeling, packaging, assembly, or manufacturing), inventory carrying costs, warehousing, and transportation.[8] Table 1 presents the five types of postponement and the cost categories related to each type.

TABLE 1

POSTPONEMENT TAXONOMY

POSTPONEMENT TYPE	PHYSICAL DISTRIBUTION COSTS
Labeling	Inventory carrying costs Warehousing Processing (labeling)
Packaging	Transportation Inventory carrying costs Warehousing Processing (packaging)
Assembly	Transportation Inventory carrying costs Warehousing Processing (assembly) Cost of lost sales
Manufacturing	Transportation Inventory carrying costs Warehousing Processing (manufacturing) Cost of lost sales
Time	Transportation Inventory carrying costs Warehousing Cost of lost sales

NORMATIVE COST MODELS

The distribution costs relevant to postponement decisions are structured in five normative models, one for each type of postponement. Each model provides a step-by-step procedure enabling managers to collect and organize cost data to support postponement decisions.

The models are independent. However, since they follow essentially the same logic, a common framework is utilized. The common framework requires an eight-step procedure based on direct and incremental costing. This type of cost data, although unavailable in many firms, is a growing part of logistics practice and literature. Direct Product Profit (DPP), for instance, is becoming increasingly common in several industries.

The use of direct (or variable) costing minimizes distortions resulting from fixed cost allocation.[9] The cost assignment criterion is all variable cost plus directly attributable fixed cost. Directly attributable fixed costs are those that would drop to zero as a result of eliminating the product.[10] Incremental costs are directly affected by the decision to postpone.[11]

The segment of the distribution channel modeled is the manufacturing plant to warehouse. The models are designed to represent a manufacturer facing a postponement opportunity. The status-quo or typical practice is assumed to be anticipatory distribution. The normative models are static replications of a single time period. Figure 1 presents the common framework.

1. Define Market - the market must be defined in terms of number and location of system destination points, plants and warehouses.

2. Define Analysis Period - the period of static analysis must be defined to guide the calculation and estimation of costs.

3. Define Products for Market and Period - all products to be distributed in the period of analysis to the market must be identified. The model recommends one outcome--postpone or anticipate--for each product.

4. Define Customer Service Level - customer service level measures physical distribution performance. Although there is an extensive literature on the measurement of customer service, postponement decisions are not affected differently by alternative measurement approaches. The firm, however, must decide on the level of performance desired in anticipatory distribution and in postponement, because varying levels of performance correspond to different levels of physical distribution cost.

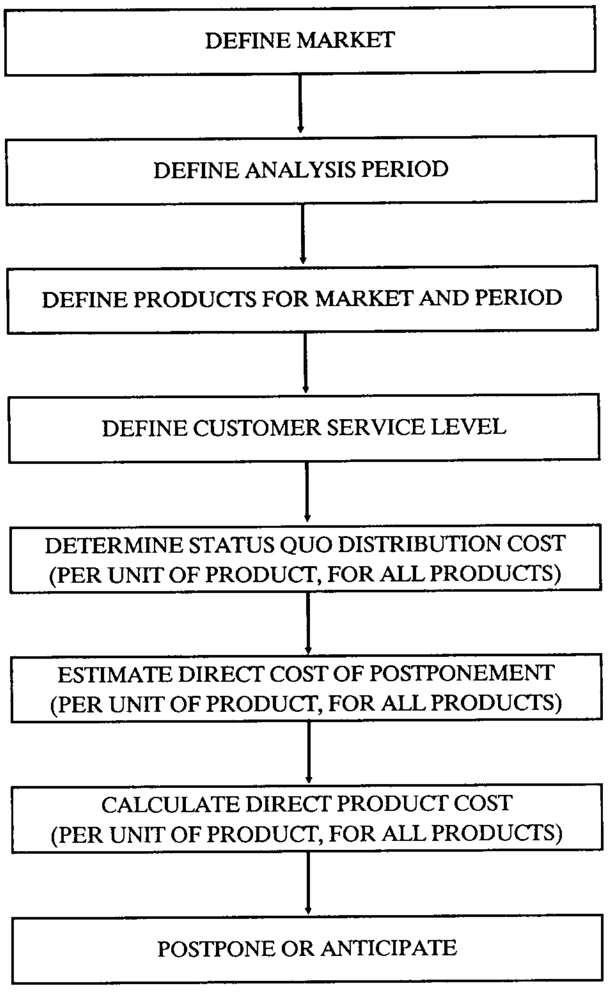
5. Determine Status Quo Distribution Cost - status quo is defined as the direct cost of distribution per period, for each product, under anticipatory distribution.

6. Estimate Direct Cost of Postponement - the direct cost of postponement per product, per period. This estimation is directly related to the level of customer service defined in step four.

7. Calculate Direct Product Cost - the direct cost per product is the difference between the measured cost of anticipatory distribution (step 5) and the projected cost of postponement (step 6).

FIGURE 1

COMMON FRAMEWORK - NORMATIVE COST MODELS



8. Postpone or Anticipate - the recommended action, based on model outcomes. There is one outcome per product, per market being studied in the period of analysis.

Model Characteristics

Each analysis model reflects different cost characteristics that are relevant to the postponement decision. For ease of classification, models are identified by a letter designation. Each model is defined in terms of postponement potential and applicable cost trade-offs. Table 2 summarizes the cost trade-offs for the five models.

TABLE 2

NORMATIVE COST MODELS COST TRADE-OFFS

NORMATIVE COST MODELS		COST CATEGORIES	COST IMPACT IF POST-PONEMENT
A	Labeling	Inventory carrying costs	DOWN
		Processing (labeling)	UP
B	Packaging	Transportation	DOWN
		Inventory carrying costs	DOWN
		Processing (packing)	UP
C	Assembly	Transportation	DOWN
		Inventory carrying costs	DOWN
		Processing (assembly)	UP
		Cost of lost sales	UP
D	Manufacturing	Transportation	DOWN
		Inventory carrying costs	DOWN
		Processing (manufacturing)	UP
		Cost of lost sales	UP
E	Time	Transportation	UP
		Inventory carrying costs	DOWN
		Cost of lost sales	UP

Model A - Labeling

Model A, labeling postponement, is based on the assumption that a product is marketed under different brand names. The model quantifies trade-offs between two basic distribution alternatives. If labels are afixed at the processing plants, the lot size of each production run is based on forecasted market demand. If labeling is postponed, products are shipped in unlabeled bright cans to the warehouse. Labeling then takes place after customer orders are received, resulting in no uncertainty regarding the quantity demanded. Canned tomatoes is an example of a product where a labeling postponement opportunity exists. Instead of stocking several brands of labeled cans, the product may be inventoried in bright cans and have the label added only when an order for one brand is received.

The cost trade-off resulting from postponement is a reduction in inventory carrying cost resulting from the consolidation of bright cans, which reduces safety stock duplication. An offset is the increase in the cost of labeling due to fewer economies of scale at the warehouse level. Economies of scale is defined as the change in average unit cost of production resulting from a change in plant size.[12] The warehouse where the product is labeled is considered as a small "plant."

Model B - Packaging

Model B, packaging postponement, is based on the assumption that a specific product is marketed in different package sizes. In the status quo alternative, products are packaged to forecast at the plant and shipped to the warehouse in anticipation of sales. When postponement is practiced, products are bulk shipped to the warehouse and packaged based on the receipt of customer orders. Laundry detergent is a product normally sold in several package sizes and, thus, could potentially benefit from packaging postponement.

The cost trade-off of postponement is an increased in per unit packaging cost resulting from loss of economies of scale at the warehouse. The favorable trade-off is a reduction in inventory carrying costs resulting from fewer stock keeping units and a reduction in transportation costs resulting from bulk shipping the detergent from plant to warehouse.

Model C - Assembly

Model C, assembly postponement, compares full assembly at the manufacturing plant to warehouse assembly to customer order. The assumption is that a base product with a number of common parts is sold in a number of configurations that are customer unique. For example, hairdryers sold in three plastic case color options. Each color is a version of a basic product. All components of the product are common, except for the plastic case.

The postponement trade-off is an increase in assembly costs at the warehouse. The potential also exists for lost sales as a result of an increase in average delivery time to customers. Average delivery time increases because the model assumes that assembly requires more time than either labeling or packaging. The cost of carrying inventories is reduced due to inventory consolidation and a reduction in transportation cost because products are shipped unassembled to the warehouses. Unassembled products typically have better density ratios than assembled, resulting in lower freight classification.

Model D - Manufacturing

Model D, manufacturing postponement, differs in degree to Model C. In anticipatory distribution manufacturing is performed at a focus plant and completed products are shipped to the warehouse in anticipation of customer orders. In postponement, parts are shipped to the warehouse, where manufacturing is completed to customer order. The basic distinction between Models C and D is the degree of warehouse assembly. In essence Model D is a complete job-shop strategy. In manufacturing postponement parts can be shipped to the warehouse from two or more locations, while in Model C parts originate from a single location. The production of soft drinks is an example of manufacturing postponement. Syrup is transported to bottling facilities where sugar and water are added to obtain the final drink.

The postponement trade-off is an increase in per unit manufacturing costs due to reduced economies of scale and potential lost sales due to an increase in delivery time. Cost reductions result from lower transportation expenditure and reduced inventory carrying costs. The key economic factor gained from multiple location supply of components is the transportation and inventory of ubiquitous materials. These materials represent low cost manufacturing inputs typically locally available, such as water. Consequently, ubiquitous materials can be obtained at very low unit transportation cost, and only negligible inventories need to be retained.

Model E - Time

Model E, time postponement, is unique in that the key attribute of postponement/anticipation is the time of shipment. Anticipation refers to a scheduled distribution situation wherein products are shipped based on forecast to warehouses. In postponement, products are shipped to customers only following order receipt, resulting in centralized inventories. Large distributors of electronic components, for instance, are centralizing inventories and reducing the number of warehousing locations in their distribution systems, to capitalize on the availability of real time communications and overnight delivery services.[13]

The cost trade-off in the decision to postpone warehouse shipment is an increase in lost sales cost resulting from longer delivery time and higher transportation costs due to a greater proportion of LTL (less-than-truck-load) shipments to warehouses. Cost decreases result from reduced centralized inventory carrying costs. If warehouses are closed as a result of inventory centralization, the Model assumes that products are shipped to a break bulk point from which a local for-hire carrier delivers to customers. The cost of local delivery in this assumption is not an incremental cost of postponement because volume shipped, shipping distance and the product itself remain the same.

RESEARCH DESIGN

For research analysis each normative cost model is structured as a simulator. Computer simulation is used to test hypotheses relating a number of product physical and demand characteristics to the five specific types of postponement.

The simulation handles product physical and demand characteristics as input variables. The distribution cost structure, based on the normative cost models, is the algorithm. The output is dichotomous. It provides the data supporting continued anticipatory distribution or postponement.

In addition to cost model assumptions, several additional parameters are needed to operationalize the simulation. These parameters are: (1) one plant and three warehouses; (2) carrying costs at 25% of inventory value; (3) safety stock equal to 2.0 standard deviations of demand; (4) cost of lost sales equal to 35% of product value; and (5) demand declines by 5% when postponement results in a reduction in customer service level.

Input

Eight product physical and demand characteristics are chosen for analysis. Three are common to all models: the level of demand, demand uncertainty, and product value. Some models have additional input. The number of brands in which a product is sold is an input to Model A, the labeling model. The number of package sizes in which a product is sold is an input to Model B, the packaging model. The number of versions in which a product is sold, and the cube reduction obtained by transporting products unassembled to the warehouse are inputs to Model C, the assembly model. The weight of ubiquitous materials, measured as a proportion of total product weight is an input to Model D, the manufacturing model. Model E, the time model, requires only the three common input variables. A value range is defined for each input. Table 3 summarizes the input variables and value ranges for each model.

The Simulator

The simulator contains four modules, each of which functions as a subroutine: Customer Service, Processing, Inventory, and Transportation. Warehousing costs are contained in the inventory module. There are five applications of the simulator, one for each normative cost model. Each module in a particular application consists of mathematical state equations used to generate cost data reflective of the normative model. The output of the simulator, a recommendation to postpone or engage in anticipatory distribution is based on the sum of lowest costs generated by the module subroutines.

Validation

Simulator application to each Model was subjected to several validation steps.[14] First, simulation and manual outputs for a number of products were compared to isolate potential program (sub-routine) errors. Second, simulation runs for a control group of ten products having desirable postponement characteristics were compared to a second group of ten products that reflect attributes favorable to anticipatory distribution. Comparative outputs were checked for surface validity that reflected if the simulator was performing according to design theory.

TABLE 3

SIMULATION INPUT

MODEL	PRODUCT PHYSICAL AND DEMAND CHARACTERISTICS	RANGE	DESCRIPTION
A	Demand	600-48000	Demand level in units.
	Uncertainty	.03-.15	Standard deviation as proportion of demand.
	Product Value	1.00-15.00	Dollars per unit.
	Brands	1-6	Brands per product.
B	Demand	600-48000	Demand level in units.
	Uncertainty	.03-.15	Standard deviation as proportion of demand.
	Product Value	1.00-15.00	Dollars per unit.
	Package Sizes	1-5	Sizes per product.
C	Demand	600-48000	Demand level in units.
	Uncertainty	.03-.15	Standard deviation as proportion of demand.
	Product Value	1.00-15.00	Dollars per unit.
	Versions	1-6	Versions per product.
	Cube Reduction	10-50	Percent, if shipped unassembled.
D	Demand	600-48000	Demand level in units.
	Uncertainty	.03-.15	Standard deviation as proportion of demand.
	Product Value	1.00-15.00	Dollars per unit.
	Ubiquitous Materials	.30-.80	Proportion of weight.
E	Demand	600-48000	Demand level in units.
	Uncertainty	.03-.15	Standard deviation as proportion of demand.
	Product Value	1.00-15.00	Dollars per unit.

Methodology

To isolate product physical and demand input variables that supported postponement, a discriminant analysis was completed. The discriminant analysis was used to derive a linear combination of independent variables that discriminate best between a priori defined groups.[15] In the analysis, postponement is the dependent variable and product physical and demand characteristics are the independent variables. The significance of each independent variable is determined by the absolute magnitude of discriminant weights, wherein a larger weight indicates greater importance.[16] For example, a high positive discriminant weight would indicate that the particular independent variable under consideration supported postponement, while a high negative discriminant weight supported anticipatory distribution.

To perform the discriminant analysis, the computer simulation results were divided into two sets, identified as analysis and hold-out. The discriminant functions, the discriminant weights, and the discriminant function correlations were based on the analysis set. The classification matrices were based on the hold-out set.

RESEARCH RESULTS

Table 4 reports the explanatory power of discriminant function correlations.[17] The coefficients are highly significant. Table 5 reports the classification matrices. The validity of results can be interpreted based on classification matrices. They show the hit-ratios, which are the percentage of products correctly classified with the discriminant function.[18] Three hit-ratios are presented for each model: products for which anticipatory distribution is recommended, postponement, and the overall ratio. Results of 73% to 92% are reasonably strong.

TABLE 4

DISCRIMINANT FUNCTION CORRELATION

MODEL	CORR. COEFFICIENT	CHI-SQUARED	D.F.	SIGNIF.
A	.74503	2249.44	4	.0000
B	.74675	251.22	4	.0000
C	.40891	92.85	5	.0000
D	.68266	193.24	4	.0000
E	.77962	337.42	3	.0000

Table 6 summarizes the analysis results. The absolute magnitude of the discriminant weights in Model A suggests that the value of a product is the most important determinant of whether labeling should be postponed. The uncertainty of the demand and the number of brands also are important.

TABLE 5

CLASSIFICATION MATRIX FOR HOLD-OUT SET

MODEL	VARIABLE	ACTUAL NUMBER OF CASES OBSERVED	CORRECTLY CLASSIFIED	ERROR	HIT-RATIO (CORR./ACTUAL)
A	POSTPONE	103	79	24	.76
	DO NOT POSTPONE	210	203	7	.96
	TOTAL	313	282	31	.90 a
B	POSTPONE	212	202	10	.95
	DO NOT POSTPONE	101	87	14	.86
	TOTAL	313	290	23	.92 a
C	POSTPONE	138	87	14	.86
	TOTAL	313	290	23	.92 a
C	POSTPONE	138	83	55	.60
	DO NOT POSTPONE	374	295	79	.78
	TOTAL	512	378	134	.73 a
D	POSTPONE	71	53	18	.74
	DO NOT POSTPONE	242	236	6	.97
	TOTAL	313	289	24	.92 a
E	POSTPONE	160	128	32	.80
	DO NOT POSTPONE	205	184	21	.89
	TOTAL	365	312	53	.85 a

a - significant at an alpha level of 5%.

Analysis indicated that thirty-two percent of the 625 products studied in this application were postponed.

In Model B, the product value was the most important predictor of postponement. Uncertainty of demand was also important. Of the 625 products studied in this application, sixty-seven percent justified postponement of packaging.

In Model C, three variables contribute to the decision to postpone assembly of a product: product value, cube reduction made by shipping unassembled goods to the warehouse, and the number of product versions offered. Twenty-six percent of the 1024 products studied in this application supported assembly postponement.

In Model D, the value of the product had a strong influence on postponement of total manufacturing of a product. Of the 625 products studied

TABLE 6

RESEARCH RESULTS

MODEL	PERCENT POSTPONED	INPUT VARIABLE	DISCRIMINANT WEIGHT
A Labeling	32	Demand	N.S.
		Uncertainty	.78
		Product Value	.84
		Number of Brands	.72
B Packaging	67	Demand	.25
		Uncertainty	.62
		Product Value	.97
		Number of Package Sizes	.36
C Assembly	26	Demand	N.S.
		Uncertainty	.31
		Product Value	.77
		Number of Product Versions	.63
		Cube Reduction	.66
D Manufacturing	22	Demand	.46
		Uncertainty	.55
		Product Value	.85
		Weight of Ubiquitous Materials	.58
E Time	43	Demand	N.S.
		Uncertainty	1.00
		Product Value	.27

N.S. - Not significant

in this application, twenty-two percent supported manufacturing postponement.

In Model E, demand uncertainty was the prime support for postponement. Forty-three percent of the 729 products studied in this application should have their anticipatory distribution to the warehouse postponed.

LIMITATIONS

As in any investigation, this research is incumbered by a number of limitations. To maintain the analysis within manageable proportions, the evaluation was of a single firm. No consideration was given to the impact on other channel members who participate in the overall distribution process.

The research is limited by a focus on individual product level. It ignores the joint relationships of product line or category impact on individual product distribution decisions. In addition, the research is limited by normative cost model and simulation assumptions described earlier.

CONCLUSIONS AND MANAGERIAL IMPLICATIONS

Despite the independence of the simulators, some patterns across results can be observed. The most promising types of postponement, defined as the likelihood that postponement will generate distribution cost savings, are found in packaging and time. Product value is the most important variable that justifies form postponement. Uncertainty of demand is the most important determinant of time postponement.

Uncertainty of demand is the second most important variable in justifying form postponement in labeling and packaging. The second most important variable in form postponement in assembly and manufacturing is transportation savings. These savings result from the reduction in cube made possible by shipping unassembled products (assembly), and the proportional weight of ubiquitous materials contained in the product (manufacturing). The level of demand is the least important variable in all types of postponement.

Table 6 also indicates that the percentage of postponed products is lower in Models C and D. This is explained by the higher cost of assembly and manufacturing when compared to labeling and packaging. As a consequence, the diseconomies of scale resulting from assembly and manufacturing at the warehouse level are also higher. Thus the cost savings in inventory and transportation needed to offset such diseconomies of scale are found in a smaller number of products.

Under specific conditions, the principle of postponement offers an opportunity for management to improve the productivity of physical distribution systems by reducing cost associated with anticipatory distribution. Transportation costs can be reduced if final processing of products can be postponed to the warehouse, therefore allowing goods to be shipped in bulk, unassembled, or over shorter distances.

Managers can also reduce their dependence on sales forecasting for allocation of products to warehouses by delaying final processing and/or the shipment of goods until a customer order is received. Finally, form postponement adds flexibility to inventories, since final processing is made to customer order. Such flexibility may be perceived by customers as an increase in service and, hence, may be a source of competitive advantage. Table 7 is based on research results. It presents the five postponement models with the conclusions as to which firm attributes may justify specific types of postponement.

TABLE 7

POTENTIAL UTILIZATION OF POSTPONEMENT

MODEL	POSTPONEMENT TYPE	POTENTIALLY INTERESTED FIRMS
A	Labeling	- Firms selling a product under several brand names - Firms with high unit value products - Firms with high product sales fluctuations
B	Packaging	- Firms selling a product under several package sizes - Firms with high unit value products - Firms with high product sales fluctuations
C	Assembly	- Firms selling products with several versions - Firms selling a product whose cube is greatly reduced if shipped unassembled - Firms with high unit value products - Firms with high product sales fluctuations
D	Manufacturing	- Firms selling products with a high proportion of ubiquitous materials - Firms with high unit value products - Firms with high product sales fluctuations
E	Time	- Firms with high unit value products - Firms with a large number of distribution warehouses - Firms with high product sales fluctuations

In conclusion, this article provided insight on how the principle of postponement can be applied to improve the productivity of physical distribution systems. Five different types of postponement were defined. Normative cost models whereby the general principle is operationalized into physical distribution costs were proposed. The article suggested a list of product physical and demand characteristics useful in identifying which products are more likely to generate distribution cost savings from postponement.

ENDNOTES

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