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DELIVERY LEAD TIME COMPRESSION: AN INTEGRAL PART OF A TIME BASED STRATEGY

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The objective of this study is to examine factors influencing delivery lead time in a manufacturing environment. It presents the results of a survey of the electronic and other electrical equipment and components industry in California to illustrate the relative importance of these factors in delivery time reduction. The degree of importance of each factor is then compared with the extent of emphasis the survey participants actually placed on the factor in attempting to reduce delivery lead time.

Corporate success in today's global environment has become increasingly dependent on a firm's ability to streamline processes and thereby decrease customer response time. The new and emerging customer-satisfaction mind set demands higher quality product, greater flexibility (in variety and volume), and better service at a competitive price within a shorter and shorter time interval. In this fast-paced global environment, more and more customers are willing to pay premium prices for faster responses to their needs. Even though quality, flexibility, service, and cost are very important factors, they are evolving into given competitive priorities that customers are not willing to compromise. The ever increasing challenge is speed and on-time delivery of customer orders–Time Based Competition (TBC).

Time Based Competition is a strategic approach of achieving competitive advantage through: (1) fast introduction of new technology and development of new products and (2) fast response to customer demands for existing products through the compression of purchasing, manufacturing and delivery lead times.[1] This study emphasizes the second portion of TBC by scrutinizing various aspects of delivery lead time reduction.

DELIVERY LEAD TIME

From a manufacturer's point of view, delivery lead time (delivery cycle) is the elapsed time between when an item is completed and available to be shipped until that item is received by the customer.[2] This time interval typically encompasses order receipt and entry, order processing, order preparation (picking and packing), and order shipment (transit time).[3] The lead time quoted to a customer (customer lead time) is often different (greater) than the delivery lead time. Customer lead time can be as short as the delivery lead time (make-to-stock environments) and as long as the total of product development, purchasing, manufacturing, and delivery lead times (engineer-to-order environments).

Initially, fueled by the application of just-in-time techniques, manufacturers strived to reduce purchasing and manufacturing lead times. Unfortunately, improvement in speed in one area can be offset by poor performance in another area. For example, in 1982, Toyota discovered that while it was able to produce a car in two days, it took from fifteen to twenty-six days to process the order, get it scheduled, and deliver the car to the customer.[4] Thus, delivery time began receiving an increasing amount of attention as a means of reducing overall response time. A study in the late 1980's indicated a shift in JIT programs focus from manufacturing to delivery lead time. This study indicated that the application of JIT has led to changes in the modes of carriage used for both inbound and outbound movements.[5] Further evidence of the growing importance of time compression has been the development of Quick Response (QR) systems in the retailing and apparel industries. Finally, more recent time based competition strategy (philosophy) is aimed at achieving supply chain integration by eliminating all "non-value-added" activities in business processes.[6]

In the area of logistics, the past two decades brought an increased recognition for an integrated business discipline which resulted in both reduced costs and increased customer service. Forward thinking firms were able to capture and retain market share through better coordination of logistics activities. This was followed by an emphasis on logistics quality aimed at increasing customer satisfaction by adding value to the firm's product via on-time, accurate, undamaged delivery. As part of this process, partnerships developed which provide additional opportunities to improve logistics quality.[7] Currently, manufacturers are striving to become more competitive through a simultaneous improvement of quality of delivery process and compression of delivery cycle.

FACTORS INFLUENCING DELIVERY LEAD TIME

From a logistics perspective, delivery lead time reduction can be achieved through both accelerating its value-added components (e.g., reduction of transit time through selection of appropriate modes of transportation and efficient vehicle routing) and elimination of non-value-added activities (e.g., elimination of the time-consuming, unnecessary administration/paperwork through the application of EDI). Typically, the initial efforts in reduction of delivery lead time, as is the case with all JIT related applications, primarily expose factors which tend to lengthen order delivery. For example, decisions made in other areas of logistics (e.g., location and number of warehouses), by manufacturing (e.g., changes in schedules), or by customers (e.g., changes in orders) can all affect a firm's ability to manage its delivery lead time. Accordingly, this study focused on eleven factors which incorporate the traditional considerations as well as contemporary TBC issues of the integrated logistics management. These factors are: 1) forecasting accuracy; 2) frequency and volume of delivery; 3) modes of transportation; 4) vehicle routing; 5) dis- tance, location, and geographical limitation of the customer; 6) containerization of delivered items; 7) transportation regulation; 8) simplified administration/paperwork; 9) product limitation/characteristics; 10) custom- er order changes; and 11) delivery schedule changes.

Forecasting Accuracy

Accurately forecasting the needs for goods at various supply points can affect the ability of a firm to provide product in a timely manner. Delivery lead time can be reduced if an accurate forecast results in making product available at forward locations (e.g., warehouses). Forecasting is also critical in the use of distribution requirements planning (DRPI and DRPII). Distribution requirements planning translates demand forecasts into a time phased replenishment plan. If stock keeping unit (SKU) forecasts are not accurate, neither is the plan.[8]

Frequency and Volume of Delivery

As frequency of delivery increases, volume of individual delivery declines. One means of shortening delivery lead time is to simply have the product delivered more often from geographically proximate locations. Higher delivery frequency can be achieved through the use of smaller capacity trucks. While there is a penalty in the form of higher transportation cost, this is offset by higher market share and resulting increased profits.[9]

Mode of Transportation

Perhaps the most obvious way to improve delivery speed is to compress transit time. Firms today realize there is a need to increasing the speed of inventory through the logistics pipeline. Transportation modal and carrier selection is an integral part of attaining that speed. However, selection must use models which consider cost in addition to timeliness otherwise what might be considered an easy way to reduce delivery time can prove to be very expensive.[10]

Vehicle Routing

Most manufacturers (industrial good producers with JIT shipments in particular) must often manage delivery of small lot sizes at great speed to their customers (original equipment manufactures). Routing vehicles (e.g., private fleet and common carriers) to connect various nodes of the distribution network (e.g., central warehouse, distribution centers, and customers locations) can profoundly effect transportation distance and, in turn, the delivery lead time.

Distance, Location, and Geographical Limitations of the Customer

Transit time is primarily a function of distance. Location decisions with respect to manufacturing and distribution facilities can have a major impact on delivery lead time. JIT suppliers often locate near major customers in order to be able to respond quickly to customer needs. In addition, suppliers can spot inventory at forward locations using public warehouses to reduce delivery lead time. While inventory requirements may be increased, more accurate forecasting can aid in keeping these increases to a minimum.

Containerization of Delivered Items

JIT manufacturers often use standard size containers to facilitate smooth flow of items between various workstations and efficient transportation of finished goods to their customers. "Standards can reduce variables to a manageable number. Unit loads, gross volumes and weights for 20-foot containers, packaging standards, pallet sizes, and so forth, make planning much easier and results more predictable."[11] Therefore, containerization of delivered items can be used as a means of stabilizing delivery lead time variability.

Transportation Regulation

Depending on the product and circumstances surrounding a shipment, various transportation regulations can act to increase delivery time. While the majority of these may relate to additional paperwork requirements, safety regulations can result in added packing, loading, and shipment preparation time. One factor that may have an impact on the delivery lead time in the future is restriction of delivery times in congested urban areas.

Simplified Administration and Paperwork

This factor relates to order receipt, entry, processing, and assembly which often require extensive administration and paper work. The application of electronic data interchange and automatic identification technology not only increases accuracy, but also reduces the process.

Product Limitations/Characteristics

A product's perishability, bulk, dimensions, and other characteristics can often lead to the need for special handling or packaging. In these cases, better planning is necessary to have appropriate resources available to handle the product. Any delays in making these resources available can delay delivery time.

Customer Order Changes

Customer satisfaction encompasses the delivery of the right product at the right time. "The problem is that customers are notoriously fickle. Just when you think you know what they want, they change their minds. Or worse yet, never make up their minds in the first place."[12] Customer order changes (e.g., changes in design, options, and quantity) create variability in the delivery process and lengthen the delivery lead time. Close cooperation and open exchange of information (partnership) between a manufacturer and its customers should minimize order changes and increase the manufacturer's ability to manage the process variability.

Delivery Schedule Changes

Delivery schedule changes have an effect similar to customer order changes. A change in the delivery schedule of an order (whether initiated by the customer or the manufacture) impacts the production system and logistics function (often with a ripple effect on delivery schedules of other orders) which will lengthen overall delivery lead time.

METHODOLOGY

A questionnaire was designed to provide a variety of information about TBC. It was composed of four groups of questions consisting a total of 228 variables. The first group of questions classified respondents based on type of goods, type of manufacturing process, number of products, number of employees, and annual gross income. This group also indicated purchasing, manufacturing, and delivery lead times as a percentage of total lead time. The next three groups of questions were designed to scrutinized various aspects of customer, delivery, manufacturing, and purchase lead times. This paper primarily concentrates on responses to the delivery lead time questions (the above eleven factors).

The electronic and other electrical equipment and components industry in the State of California provided the frame for the survey. The responses of manufacturing firms with one hundred or more employees and $5,000,000 or more annual gross sales were used to complete this research.

The 1995 edition of the *California Manufacturer Register*[13] and *The American Business Disc*[14] were used to develop the mailing list. The 3612 through 3699 S.I.C. codes were the bases of identifying the appropriate manufacturing firms. A total of 648 manufacturing firms constitute the survey group. Questionnaires were mailed to the firms' representatives such as chief executive officer, president, vice president of manufacturing, and plant manager. Three weeks later a follow-up letter was sent to each of these manufacturing firms. Telephone calls were also made to a randomly selected number of firms to remind them of the importance of this research. All efforts yielded 51 usable responses. The relatively low usable response rate could be attributed to: (1) the comprehensive, exploratory, time-consuming nature of the questionnaire; (2) the multi-disciplinary (purchasing, manufacturing, and delivery functions) nature of the research; and the research delimitation (inclusion of manufacturing firms with one hundred or more employees and $5,000,000 or more annual gross sales).

THE SURVEY RESULTS: EMPIRICAL EVIDENCE

Many practical and interesting results were drawn from the findings of this research. The results related to delivery lead time reduction are presented in this paper. They are divided into four groups: (1) the respondent profile; (2) components of total lead time; (3) factors influencing delivery lead time reduction; and (4) emphasis placed on factors reducing delivery lead time.

The Respondent Profile

Table 1 presents the profile of participating manufacturing firms. These firms were representatives of a cross-section of different processing environments, number of products or variation of products, and annual gross sales. A majority of these firms (74.5%) employed 101 to 500 employees. Finally, these firms, on average, produced significantly more industrial goods (71.2%) than consumer goods (21.0%). Since 60% these firms produced 90% or more industrial goods, conclusions drawn from the data received relate more to the delivery lead time of industrial, rather than consumer goods.

Components of Total Lead Time

Since total lead time, from a TBC perspective, includes purchase, manufacturing, and delivery lead time, firms were initially asked to estimate the percent of total time most commonly consumed by each. Results shown in Table 2 indicated that the percentages of purchase and manufacturing lead times were almost equal and accounted for the majority of total lead time.

TABLE 1
Profile of Participating Manufacturing Firms

Category	Percent	Category	Percent
Manufacturing Process		Number of Products or Variation of Products	
Job Shop	21.6	0-50	17.6
Batch	31.4	51-100	15.7
Repetitive	25.5	101-250	21.6
Continuous	13.7	251-500	7.8
Other	3.9	501-1,000	15.7
Missing Values	3.9	Over 1,000	19.6
		Missing Values	2.0
Number of Employees			
101 to 250	35.3	Annual Gross Sales	
251 to 500	39.2	$5,000,001 to $20,000,000	15.7
501 to 1,000	7.8	$20,000,001 to $50,000,000	33.3
1,001 to 2,500	9.8	$50,000,001 to $100,000,000	19.6
Over 2.500	7.8	$100,000,001 to $500,000,000	17.6
		$500,000,001 to $1,000,000,000	5.9
		Over $1,000,000,000	7.8
Type of Goods (Products)*			
Consumer Goods	21.0		
Industrial Goods	71.2		
Other	7.8		

* The percentages are averaged for all respondents

This illustrates why firms commonly address manufacturing and purchase lead time first when attempting to compress total lead time. However, as previously mentioned, many firms have achieved decreased customer response time in these two areas and are now taking a closer look at the delivery lead time component.

Factors Influencing Delivery Lead Time Reduction

Using a seven-point ordinal scale (1 = not important to 7 = very important), the respondents were asked to indicate their opinion (belief) of the importance of each of the eleven factors discussed previously in reducing delivery lead time in their manufacturing firms. Using a similar scheme, the respondents were also asked to indicate the extent to which their firms currently emphasize (1 = no emphasis to 7 = great emphasis) each factor in reducing delivery lead time.

TABLE 2
Components of Total Lead Time

Category	Percent*
Purchase Lead Time	42
Manufacturing Lead Time	43
Delivery Lead Time	11
Other**	4

* The percentages are averaged for all respondents.
** This category included the product development lead time.

Table 3 presents these factors in descending order of their reported degrees of importance. This table also presents mean scores and ranks of the importance of each factor, mean scores and ranks of the emphasis placed on each factor, mean comparisons (t-values and

and two-tail significance) of the two categories of responses (emphasis versus importance), and the Wilcoxon Matched-Pairs Signed-Ranks Test for the two categories of responses (emphasis versus importance).

The top six factors listed, comprise a group of elements which can be considered to have an above average importance in attempting to reduce delivery lead time. The rank and mean value for forecasting accuracy indicates the paramount importance of this factor in enabling a manufacturer to effectively plan for the speedy delivery of orders. This is the core of quick response systems. The availability of current demand data provides a firm with an ability to have products available in the right place at the right time to satisfy customer needs. Of course rapid communication of these data between all parties involved (carriers, suppliers, and customers) is critical in compressing delivery lead time.

Frequency/volume of delivery and simplified administration/paperwork were ranked high–as one might expect–and considered as important ways of reducing delivery lead time. Interestingly enough, these two factors are closely related. More frequent deliveries often require increased paperwork. Unless appropriate technology is utilized and efficient processes are developed to eliminate non-value added tasks, attempts to shorten delivery lead time can be thwarted by multiplying administrative barriers. In this case internal communication must ensure that shipments are not delayed because they are waiting for paperwork.

From a systems perspective, changes in customer orders and delivery schedules can lead to increased variability in various manufacturing processes. Respondents' placing above average degrees of importance on these factors reiterated the importance of process stability. Evidently, participating manufacturers believe that delivery lead time can be reduced in an stable environment, and stability can be achieved through management (reduction) of delivery schedule and customer order changes.

The final factor which ranked above average in importance relates to the physical characteristics of the product itself. Assuming that these characteristics cannot be altered via design changes, reducing lead time would rely on improving the processes required to accommodate a product's special needs. This may relate to loading, packing, or any number of other handling needs.

One of the more surprising results is the low importance placed on transportation related factors. Modal selection, routing, distance, and regulation all ranked toward the bottom. Since transit time is such an important factor in determining delivery lead time, one would assume it would be an important means of time compression. However, the reality is that there are limits upon the ability to compress this time. Once initial improvement in transit time occurs, there are very limited opportunities to further reduce it. If this is the case, responding firms may have already done what is necessary to speed movement and are now focusing on other factors.

Emphasis Placed On Factors Reducing Delivery Lead Time

A comparison of the emphasis placed on each of the above factors with its stated importance reveals a constant belief that attention to these factors is lagging. A lack of sufficient emphasis might indicate that those who make decisions about resources or set priorities are unaware of the extent to which these factors can impact delivery time. Once again, logistics managers are faced with the task of communicating the importance of the integrative logistics activities.

For the six factors which were reported to be the most important in reducing delivery time, five were identified as not receiving enough emphasis. This was particularly true of the two factors which ranked the highest in importance: forecast accuracy and frequency/

TABLE 3
Factors Influencing Delivery Lead Time Reduction

	Importance		Emphasis		Mean Comparison (Emph. vs. Import.)		Wilcoxon Test (Emph. vs. Import.)	
Factors	Mean	Rank	Mean	Rank	*t*-value	Signif.	Z Value	2-Tailed *p*
Forecast Accuracy	5.57	1	4.96	1	-2.97	0.005*	-2.6571	0.0079*
Frequency & Volume of Delivery	4.76	2	4.12	3	-2.85	0.007*	-2.5547	0.0106*
Simplified Administration/ Paperwork	4.55	3	4.11	4	-1.47	0.148	-1.4004	0.1614
Delivery Schedule Changes	4.48	4	4.19	2	-2.10	0.042*	-1.8713	0.0613
Customer Order Changes	4.44	5	3.84	6	-2.75	0.009*	-2.4674	0.0136*
Product Limitation/Characteristic	4.35	6	3.85	5	-2.34	0.024*	-2.3893	0.0169*
Distance, Location, & Geographical Limitation of the Customer	3.42	7	3.11	7	-1.74	0.090	-1.6053	0.1084
Modes of Transportation	3.16	8	3.00	8	-0.98	0.333	-0.9581	0.3380
Containerization of Delivered Items	2.67	9	2.60	9	-0.75	0.457	-0.8891	0.3739
Vehicle Routing	2.60	10	2.32	10	-2.32	0.026*	-2.1339	0.0329*
Transportation Regulation	2.40	11	2.10	11	-1.67	0.103	-1.5297	0.1261

* Two-tail significance $\leq$ 5%.

volume of delivery. Only in the case of simplified administration and paperwork did re- spondents feel that a balanced attention was being given to an important delivery time reduction factor. This is not surprising since order entry, processing, and assembly time (all requiring administration and paperwork) have long been recognized as major elements in determining the length of delivery lead time. Therefore, these elements (in turn, adminis- tration and paperwork) have been the target of technology applications, process improvement, and reengineering. However, manufacturers need to place higher degrees of emphasis on the remaining top five important factors if they wish to further compress their delivery lead times.

The five factors which were ranked the lowest in importance, in general, were identified as being adequately stressed in lead time reduction strategies. Again, the highly visible nature of transportation may be responsible for the attention that has been paid to all but one of these factors in the past, resulting in adequate corporate responses. The single exception was vehicle routing, a factor which is of great importance to firms in a JIT environment. Therefore, even though this factor ranked low in importance, it is seen by some firms as requiring additional attention.

CONCLUSIONS

Traditional means of reducing delivery lead time tend to focus on compressing one of its four major components: Order entry, order processing, assembly, and transit time. Information provided by respondents in this study indicate that other factors may also be important in attempting to decrease delivery lead time and thereby become more responsive to customers. It appears that factors related to transportation and paperwork have been dealt with, to some degree, and are currently being emphasized in lead time reduction strategies. In answering the challenge of time based competition, however, other factors including forecasting accuracy, frequency of delivery, order changes, and delivery schedule changes require additional emphasis. While this study is limited by its focus on a single industry, the concepts discussed may, in fact, be applicable in other industries. In any case, it is apparent that logistics managers must recognize the fact that delivery lead time reduction may require examining more factors and processes than have traditionally been considered.

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