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A Review and Evaluation of Logistics Performance Measurement Systems

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Logistics encompasses a complex set of activities which require a collection of metrics to adequately measure performance. Ideally, the performance metrics used should be selected and maintained as a system, so they complement and support each other and provide the decision makers with a well balanced picture of the logistics process. Often in practice, however, performance measurement systems are not formally managed or evaluated. The result is a performance measurement "system" where the interrelations between the metrics are not known, duplication is frequent, and omission is undetectable. This paper addresses this shortcoming by developing a set of evaluation criteria for logistics performance measurement systems and applying it in two case studies.

Unfortunately, many performance measurement systems have neither kept up with the changing role and scope of logistics nor have they been systematically examined or evaluated.

Over the last decade, the role of logistics in business has increased in both scope and strategic importance. Initiatives, such as supply chain integration, quick response, and just-in-time inventory management, have revolutionized not only the way companies manage their logistics activities, but also how they run their entire business. Logistics strategies have influenced customer selection, product design, partnership/alliance building, vendor selection, and many other core business processes. Unfortunately, many performance measurement systems have neither kept up with the changing role and scope of logistics nor have they been systematically examined or evaluated.

Performance measurement systems should be evaluated at both the *individual metric* and *system-wide* levels in order to maintain relevance and effectiveness. While Caplice and Sheffi [1] present an approach for evaluating individual performance metrics, this paper addresses the evaluation of logistics performance measurement systems as a whole.

Specifically, there are two objectives:

1. Establish useful criteria which can be applied to evaluate logistics performance measurement systems, and
2. Demonstrate the use of these criteria through the evaluation of two companies' performance measurement systems.

The primary motivation for evaluating performance measurement at the system level is that measurement systems guide management decisions. A well crafted system of metrics will lead towards better decision making by managers. A measurement system, therefore, should be more than a disparate assortment of individual metrics; it must be cohesive, comprehensive, and complementary. Keegan, Eiler, and Jones [2] note that for most companies "the problem is that *there are too many performance measures* – too many that are obsolete and too many that are not consistent." While performance measures will readily accumulate, it is rare that they are removed. This results in performance measurement systems based on what Keegan, et al. describe as "the ghosts-of-management-past." Even if new metrics are rigorously examined, existing metrics are typically not reviewed in the context of the entire system which could result in an outdated and untested performance measurement "system" where the interrelations between the metrics are not known, duplication is frequent, and omission is undetectable.

This paper does not suggest specific metrics or sets of metrics to be used by a firm. Product characteristics, management focus, marketing channels, the competitive situation, and other factors create a unique logistical environment for each company which requires a customized performance measurement system. While it is unlikely that a single set of metrics capturing every nuance of every companies' logistics operations even exists, a set of common characteristics of "good" measurement systems can be developed. The contribution of this paper, then, is the development of a useful set of evaluation criteria which can be used to determine the strengths and weaknesses of a firm's logistics performance measurement system.

The remainder of the paper is organized into three sections. The first section reviews the relevant literature. The second section proposes a set of evaluation criteria and discusses some managerial implications of adopting these criteria. Finally, the evaluation criteria are used in the third section to assess two actual performance measurement systems.

Literature Review

Four common principles concerning performance measurement systems can be drawn from the business strategy, management control, and the managerial accounting literature. First, a measurement system should be comprehensive in that it should capture performance from more than one perspective. Kaplan and Norton [3,4], Chakravarthy [5], Harrington [6], Maisel [7], and others argue for measuring along multiple dimensions of performance to capture all relevant stakeholders. Kaplan and Norton, for example, suggest that four "dials" or perspectives be considered for performance measurement: customer (service quality), shareholder (financial results), internal (process efficiency), and innovation/learning.

Second, the system should be *causally oriented* by capturing the drivers of performance rather than just the end results. For example, Eccles [8], Fisher [9], Kaplan [10], Howell, Brown, Soucy, Seed [11] and others stress the importance of including nonfinancial metrics, which drive the financial results, in measurement systems. Systems with metrics of this sort can provide deeper insight into performance than purely financial measurement systems.

Third, a performance measurement system should be *vertically integrated* by linking the overall corporate strategy to the particular types of decision making at each level in the organization. Lynch and Cross [12] and Ernst & Whinney [13] illustrate the importance of aligning lower level performance measurement systems with firm-wide objectives to encourage what Anthony [14] refers to as "goal congruence."

Finally, performance measurement systems should be *horizontally integrated* or aligned along a process rather than with each function or department. Lee and Billington [15], Maisel [7], Keegan, et al. [2], and others describe how measurement systems which concentrate on functional areas can discourage coordination and lower overall system performance. This is a primary emphasis of supply chain integration initiatives.

The contribution of this paper, then, is the development of a useful set of evaluation criteria which can be used to determine the strengths and weaknesses of a firm's logistics performance measurement system.

In the logistics literature, more attention has been placed on individual measures than on systems of measures. For example, while A.T. Kearney [16] discusses individual performance metrics in great detail, they do not address characteristics of systems of measures at the same depth. They note that logistics management and measurement should (1) focus on logistics service quality, (2) have a process perspective, and (3) emphasize the importance of the customer. They also recommend other implementation considerations, such as, having the proposed system on the senior executive's agenda, including input from all levels of employees, ensuring that the selected metrics "relate to providing customer and shareholder value," and tying the measurement system to the bonus and compensation systems.

In the logistics literature, more attention has been placed on individual measures than on systems of measures.

Van der Meulen and Spijkerman [17] and NEVEM [18] evaluate logistic metrics at the individual and system levels and recommend using financial data to measure the overall performance in the form of a detailed return on investment (ROI) calculation. This logistics input/output model ties together the individual departments within the logistics process using financial values of the product. Additionally, they argue that any set of performance metrics should (1) represent performance indicators in the logistic chain, (2) include financial and control elements, (3) distinguish between

Table 1
Evaluation Criteria Summary

Criterion	Description
Comprehensive	The measurement system captures all relevant constituencies and stakeholders for the process.
Causally Oriented	The measurement system tracks those activities and indicators that influence future, as well as current, performance.
Vertically Integrated	The measurement system translates the overall firm strategy to all decision makers within the organization and is connected to the proper reward system.
Horizontally Integrated	The measurement system includes all pertinent activities, functions, and departments along the process.
Internally Comparable	The measurement system recognizes and allows for trade-offs between the different dimensions of performance.
Useful	The measurement system is readily understandable by the decision makers and provides a guide for action to be taken.

different levels in the organization, (4) indicate the relationship between logistics functions, and (5) be capable for use as a calculation model in order to obtain quantifiable results.

Andersson, Aronsson, and Storhagen [19] note that logistics performance measurement systems are typically split between measuring either internal efficiency or external effectiveness rather than capturing both. This creates a "measurement gap," where financial ratios (such as ROI) are used to communicate results "upwards" to senior management while physical measures (such as timeliness, and utilization) are used to communicate "downwards" to the operational level. They argue that one objective of a measurement system is to close this gap. Similarly, Mentzer and Konrad [20] note that performance measurement should include the "analysis of both effectiveness and efficiency in accomplishing a task." They also describe a 12 step implementation process which focuses primarily on developing control metrics for cost containment and budgeting.

A logistics performance system is* comprehensive *if it captures the effect that a policy has on each of the relevant stakeholders.

Proposed Evaluation Criteria

Based on the literature review and company interviews, six criteria were selected as being the most relevant when evaluating a logistics performance measurement system. A "good" system should be *comprehensive, causally oriented, vertically integrated, horizontally integrated, internally comparable,* and *useful.* The first four criteria correspond to the four points drawn from the managerial accounting literature. Table 1 summarizes these criteria and the remainder of this section describes each in more depth. Evaluation criteria are printed in italics for the remainder of the paper.

***...six criteria were selected...*comprehensive, causally oriented, vertically integrated, horizontally integrated, internally comparable, *and* useful.**

Comprehensive

A logistics performance system is *comprehensive* if it captures the effect that a policy has on each of the relevant stakeholders. For example, a measurement system which contains only financial metrics such as ROI and variance from budget would not be *comprehensive* since it ignores the customer's perspective. A major problem with the traditional measures used for expense centers is that they are not comprehensive. Fortuin [21] refers to reliance on noncomprehensive performance measurement as "one-dimensional management" which just "moves problems around rather than solving them." While there are a large number of potential performance dimensions, the three most basic ones are customer satisfaction, internal process efficiency, and financial results. Other dimensions may be included if management feels that they are relevant to long-term performance. For example, a chemical company includes environmental/safety as a separate performance dimension of equal importance as cost and customer satisfaction.

Causally Oriented

A performance measurement system is *causally oriented* if it tracks root causes of performance, not just end results. For example, monitoring customer satisfaction by tracking sales revenue is not as *causally oriented* as, say, the order cycle time since this response time might be the primary factor which retains customers and thus drives ultimate future performance. Using *causally oriented* metrics in a logistics performance measurement system raises the visibility of long term objectives and usually manifests itself in the form of more nonfinancial measures.

Nonfinancial measures tend to indicate future performance, while financial metrics are lagging indicators with an internal focus which may encourage myopic decision making. The problems associated with using only financial metrics in a measurement system are well documented by Eccles [22], Kaplan [10], Mitchell [23], and Howell, et al. [11]. While there are numerous benefits to using nonfinancial metrics in a logistics performance measurement system, there are also some drawbacks. It is difficult to find any form of correlation between different types of nonfinancial measures. Fisher [9] notes that they cannot be easily "dollarized" for comparisons to costs making the connection between nonfinancial improvements and profitability difficult to establish. Also, McNair, Lynch, and Cross [24] note that often financial and nonfinancial measures will not agree since improvements to the operational aspects which show up in the nonfinancial measures do not immediately turn into profits recognized by the financial metrics.

Vertically Integrated

A performance measurement system is *vertically integrated* if it translates the overall strategy of the organization to all decision makers within the organization and connects metrics at each level to the appropriate reward system. Unfortunately, many of today's performance measures promote and reward behavior that may hurt a company's overall performance due to a mismatch between functional and corporate goals. For example, Carlzon [25] relates the case of an airline that advertised itself as the "precision airline" for its air cargo business, but measured performance entirely on volume carried and whether the billing information became separated from the actual cargo. A separate test of the system showed that deliveries were on average four days late, but the bills were hardly ever separated from the cargo. The operation was following where it was being measured, rather than where the corporate strategy wanted it to go. As Anthony [14] notes, a performance measurement system "should be designed so that actions that it leads people to take in accordance with their perceived self-interest are actions that are also in the best interests of the organization; that is, the management control system should encourage goal congruence." This requires that different levels of the organization use different, yet related, metrics since the types of decisions made at each level are different.

A performance measurement system is* causally oriented *if it tracks root causes of performance, not just end results.

Horizontally Integrated

A performance measurement system is *horizontally integrated* if it includes all pertinent activities, functions, and departments along the process. Lee and Billington [15] rank the lack of horizontally integrated metrics as the first pitfall of supply chain integration. They note that a measurement system should contain metrics that capture the activities across the different functions and balance against each other. For example, measuring inventory levels via turnover rate across the supply chain, be it system-wide or segregated by stage, should be balanced with a metric capturing service levels across the supply chain. A logistics performance measurement system should encourage, or at least not discourage, integrating operations along the entire supply chain.

...*horizontally integrated *if it includes all pertinent activities, functions, and departments along the process.

By focusing on the entire supply chain, a measurement system encourages innovative approaches to logistics. If, for example, a logistics performance measure is tied to increased market share then the "good" logistics manager is going to explore those alternatives which might lead to this goal which do not normally fall within the logistics activity realm. Byrnes and Shapiro [26] note that the current "inward looking" performance measures tend to reinforce the lack of intercompany (and, we add, interfunctional) operating ties. These traditional performance measures capture efficiency and service levels responding to orders already placed rather than trying to

...*vertically integrated *if it translates the overall strategy of the organization to all decision makers...

modify the order patterns themselves by working with suppliers and buyers as partners.

Internally Comparable

A performance measurement system* is internally comparable *if trade-offs between the different dimensions of performance can be made.

A performance measurement system is *internally comparable* if trade-offs between the different dimensions of performance can be made. This is easy when only financial metrics are used: x dollar increase in costs should gain at least x + y dollar increase in revenues. However, when the system becomes more *comprehensive* this becomes more difficult to identify and quantify. For example, a system of measures should attempt to answer how much a 10% decrease in cycle time is worth in terms of additional costs incurred and potentially higher customer service levels. This criterion states that a measurement system should try to incorporate some idea of how the different performance dimensions can be traded-off between each other. Note that the trade-offs here are not between the evaluation criteria, such as being comprehensive versus being useful but rather between the individual metrics and the performance dimensions, such as how does increasing on-time deliveries affect ROI?

Useful

...useful *if it is readily understandable by the decision maker and provides a guide for action to be taken.*

A performance measurement system is *useful* if it is readily understandable by the decision maker and provides a guide for action to be taken. Keegan, et al. commented that one should "seek elegance and simplicity" when designing a performance measurement system since overly complex systems will end up either being ignored or discarded after a relatively short period of time. Measurement systems that produce seemingly arbitrary performance levels are typically treated as black boxes and are either not trusted or simply not used.

Managerial Implications

This ability to guide and influence the decision making process is actually the ultimate goal of any measurement system.

Taken collectively, these criteria can transform a measurement system so that the entire management approach towards logistics needs to be changed. This ability to guide and influence the decision making process is actually the ultimate goal of any measurement system.

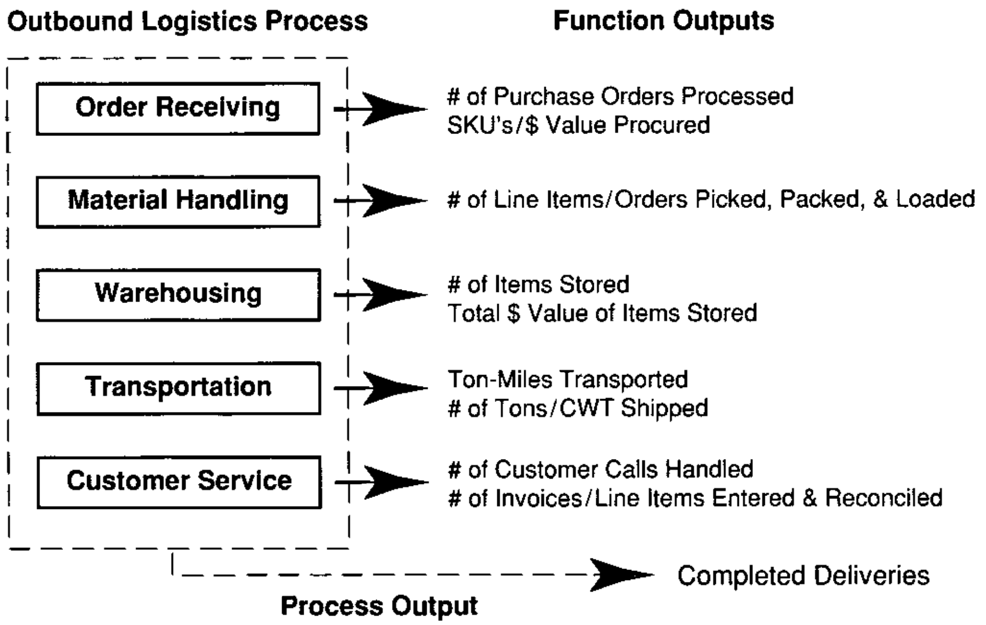
Traditionally, logistics was treated as an expense center, producing a standard and comparable form of output, such as ton-mile [27]. Naturally, most logistics performance measurement systems concentrated on monitoring resource consumption, for example costs, in order to promote efficiency in producing this standard output. Because logistics has grown in scope over the last decade, this approach is no longer valid. Specifically, three upper management realizations preclude the management of logistics as an expense center: logistics output is not standard, logistics adds significant value to customers down the supply chain (not just costs), and logistics service level is a critical component of customer satisfaction.

Likewise, the six evaluation criteria would not work well if simply grafted onto an expense center management approach. Instead, the form of management, with a different underlying conceptual model, may have to change along with the performance measurement system. Various researchers have proposed different approaches for measuring and managing logistics, such as the quantifying of logistics value [28], the total cost/value model for supply chains [29], and others. In general, two points should be stressed in any management or measurement system.

First, the definition of output should be transaction based. For logistics, the basic transaction is a completed delivery to a customer. Because the entire process is required to provide a completed delivery, this definition of output includes all sub-activities within the process, not just one function's contribution, as shown in Figure 1.

Second, the system needs to focus on the downstream player in the supply chain, the customer. Because each transaction represents a discrete opportunity for meeting or failing some or all of a customer's requested standards, we can classify the output as being either perfect or not by comparing each completed delivery to the characteristics requested by the customer. This distinction between the *promised* demand and the *provided* output permits a measure of effectiveness based not on internal standards, but rather on customer requirements. Several cutting edge companies have begun to incorporate this concept of output under such names as Perfect Orders, Flawless Fulfillments, Perfect Installations and others.

Figure 1
Function Versus Process Output For Logistics



A simple schematic of a model which incorporates these features is shown in Figure 2. Adapted from the Socio-technical System Model introduced by Adam, Hershauer, and Ruch [30], it consists of three components: inputs, demand information, and outputs. Input is defined as all resources utilized during the process, demand information as service requirements requested by each customer, and output as completed deliveries of products to the customer (segmented into perfect and imperfect deliveries).

In summary, the use of these evaluation criteria imply a certain managerial approach. The *comprehensive* criterion requires the measurement system to bring both balance and breadth to decision making, while the *causally oriented* criterion brings greater depth by focusing on root causal factors rather than after-the-fact-results. The *vertically* and *horizontally integrated* criteria reinforce the measurement system's objective of unifying all decision makers within a firm and along the supply chain, respectively. By being *internally comparable*, a measurement system can be used to quantitatively trade-off benefits in one area against costs in another; it allows for interaction between the various performance dimensions. Finally, the *useful* criterion keeps the measurement system as simple and insightful as possible. These six criteria can represent more of a change in management practice then a simple change in measurement procedure.

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Case Studies

This section discusses the logistics performance measurement systems used by two firms. The firms were selected primarily for their differences in approach, product, and markets in order to illustrate the similarities and differences in performance measurement systems.

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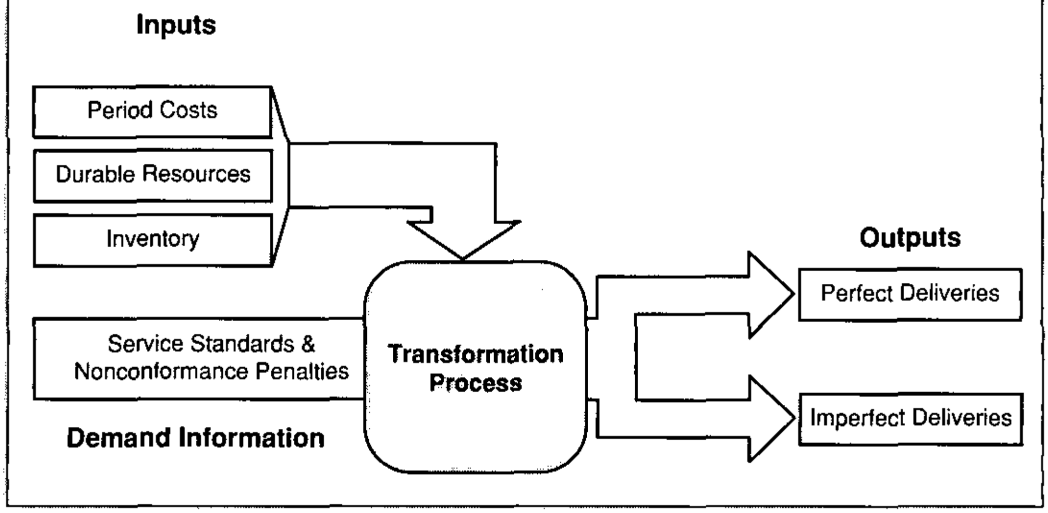
Case Study I: Goodyear Tire & Rubber Co., Inc.

Goodyear's primary business is the development, manufacture, and distribution of tires for automobiles, trucks, buses, farm and earth moving machinery, airplanes, and various other equipment. It has several plants and distribution centers (DCs) in the US to serve this business. The Logistics and Product Supply (L&PS) department, under the Materials Management Division, controls the supply chain from the manufacturing plants, through the DCs to the customers. It includes order processing, shipping, receiving,

Figure 2
Conceptual Model of Logistics Process



distribution, packaging, materials handling, warehousing, inventory control, transportation, and production planning.

Goodyear sells tires through two distinct distribution and marketing channels: replacement or renewal (REN) dealers and original equipment manufacturers (OEM). The REN channel serves dealers and is substantially larger than the OEM channel in both sales and number of customers. Standard orders in the REN channel are shipped to each customer location on a scheduled weekly pick cycle. The OEM channel serves manufacturers, with the tires often feeding directly into production lines. Since most of these manufacturers are using JIT techniques, the service standards, such as on-time windows and fill rates, are much higher than in the REN channel. The major differences between the channels are that OEM customers (1) have higher expectations, (2) require more stringent service standards, and (3) demand additional value-added services.

The major strength of the system is that it is comprehensive in scope...

Goodyear's Measurement System. Recently, L&PS helped write up a business plan for the REN channel to include a measurement system identifying four specific performance dimensions: *Customer Focus, Human Resources, Asset Management*, and *Process Management*. Each of the performance dimensions has a set of supporting indicators which are summarized in Table 2.

These metrics are reported monthly and tracked over time. Performance for each warehouse is compared against the others and to an overall average with the understanding that product mix varies dramatically between them. These measures serve to indicate any problems and, as such, have supporting diagnostic measures behind them. For example, while Goodyear's metric titled *customer satisfaction* captures the number of missent items, diagnostic metrics can be used to identify specifically which shipments, products, customers, and DCs were involved. In addition to these metrics there is a separate Logistics Cost Management analysis which tracks the cost for corporate logistics, customer service/order processing, field warehousing, and transportation on a cost per unit (tire) basis. Also, the logistics cost is tracked as a percentage of net sales, gross sales, and corporate overhead.

Discussion. The major strength of the system is that it is *comprehensive* in scope in that four distinct dimensions of performance are captured. When combined, these dimensions cover the entire process of distributing tires through the various DCs to customers (dealers): the *Human Resources* and *Asset Management* dimensions track the critical inputs (labor, spending, and inventory), the *Process Management* dimension captures the transformational efficiency of the process, and, finally, the *Customer Focus* dimension measures the quality of the output. It was felt that due to the labor intensity of distribution's activities, a separate group of metrics was justified.

Table 2
Summary of Goodyear's L&PS Performance Measurement System

Performance Metric	Description
Customer Focus	
Customer Satisfaction	The number of incorrect tires shipped out; measured in parts (or tires) per million (ppm) shipped.
Order Fill Rate	The number of tires which were filled measured as percentage of total ordered.
U.S. Forecasted Demand versus Shipments	The actual shipments from DCs measured at the SKU level subtracted from the final forecasted volume generated 2-3 months prior. Absolute error is measured so that under and over shipments don't cancel out.
Human Resources	
Staffing	The actual number of employees per department compared to the pre-determined objectives or targets.
Safety	The number of incidents causing lost time.
Attendance	The rate of truancy among employees.
Asset Management	
Budget versus Actual	The comparison of the planned budget against the actual budget.
Inventory Investment	The dollar value amount of inventory at each DC for all phases of product (raw, WIP, finished product, and total).
Process Management	
Productivity	The number of tires processed divided by the total number of man hours (direct & indirect) at the DC.
Distribution Cost per CWT	The total distribution cost per hundred weight of product in each DC.
Transportation Cost per CWT	The total accumulative freight expense to the customer per hundred weight shipped.

The system's primary weakness is that it is not as horizontally integrated as it potentially could be; the individual metrics capture performance at the distribution center and only indirectly infer the customer's satisfaction with the delivery service. For example, the metrics do not capture any time measurement from the customer's perspective. Additionally, there is no direct measurement of the performance of the intermediate players (the carriers). Goodyear is in the process of developing new measures which track the accuracy, reliability, and responsiveness of shipments to include order cycle time and transit time to the customer.

The system is generally *causally oriented* in that a number of drivers of future performance are tracked, especially in the *Customer Focus* and *Human Resources* dimensions. For the *Customer Focus* dimension, the customer satisfaction and order fill rate metrics capture aspects which contribute to higher levels of customer satisfaction and translate into increased market share. For the *Human Resources* dimension, the metrics safety and attendance provide upper management indicators of the workers' attitudes which is a significant driver of future output. Note that all of these metrics, while *causally oriented* are also internally focused.

In summary, the measurement system is well suited to Goodyear's L&PS operations. It is *comprehensive* in that it includes multiple performance dimensions. It is *useful* in that it emphasizes those things which are particularly important to the tire logistics process: the mispicking problems (as seen in a separate measure for mispicking of tires) and the heavy labor component (*Human Resources* metrics). The primary weakness of this measurement system is its internal focus which manifests itself in the lack of metrics

In summary, the measurement system is well suited to Goodyear's L&PS operations.

tracking delivery to the customer's door. This is a common weakness for logistics performance measurement systems in general, and is currently being addressed at Goodyear. Table 3 summarizes this discussion.

Case Study II: Digital Equipment Corporation

Digital is employing a balanced scorecard approach to the measurement of performance...

Digital Equipment Corporation is one of the world's largest information systems supplier and workstation manufacturer. Its products include a full range of computer systems and networks, data storage devices and printers, industrial software, and services. Traditionally, Digital's customers have been Fortune 1,000 firms that required large scale mainframe computers with unique system capabilities. Recently, however, businesses have been moving towards smaller minicomputers, workstations, and personal computers leading Digital to expand into the more competitive, and lower margin PC market. Because these are different types of products with extremely different customers, competitors, and service requirements, Digital distributes them through two distinct channels: traditional and on-demand. A third channel, system integration, focuses on installing entire information systems and is not in place, yet.

The traditional channel consists of the build-to-order systems where a specific computer or system is designed and built for a specific customer. These tend to be unique large scale main-frames requiring extensive service. In contrast, the on-demand channel consists of low-end commodity type items, such as PCs and printers, which are pre-built and can be purchased off the shelf. These products are distributed both through retailers and directly to consumers.

Digital's Measurement System. Digital is employing a balanced scorecard approach to the measurement of performance based upon the work by Kaplan and Norton. While Kaplan and Norton identified four performance perspectives for management to measure (customer, internal, shareholder, and innovation), Digital has decided to include only the first three. Table 4 shows each of the three perspectives and the corresponding metrics.

Each quarter, five values are reported in a graphical format for each of the metrics: current quarter's performance, world class value (top 20% of similar firms), performance standard (internal goal), industry average (similar firms), and fiscal year goal. This allows for a quick assessment of the competitive standing of Digital in each performance area which is seen as being more important than volume based

Table 3
Summary of Evaluation of Goodyear's L&PS's Performance Measurement System

Criterion	Description
Comprehensive	The system incorporates the three major dimensions of performance (customer, process, and financial) while including a *Human Resources* dimension, as well.
Causally Oriented	This depends on the dimension. While the *Customer Focus* and *Human Resources* dimensions are driver oriented, *Asset Management* and *Process Management* are not. Note that there are no time metrics at all.
Vertically Integrated	These metrics appear to be directly applicable to sub-units.
Horizontally Integrated	While designed to be horizontally integrated, the individual metrics are the limiting factors. The *Customer Focus* metrics do not measure to the customer, but, *Process Management* captures total cost to customer.
Internally Comparable	While recognized as being interrelated, there is no formal way to trade-off performance along the different dimensions.
Useful	The system is very useful in that it is action oriented and easily understood.

Table 4
Summary of Digital Equipment Company's Supply Chain Metrics

Metrics	Description
Customer Metrics	
Predictability	The percentage of orders which meet the on-time commitments made to customers.
Responsiveness	The average offered (advertised) cycle time for deliveries.
Customer Satisfaction	Customer perception of ease of doing business with Digital as measured by survey results.
Annual Rate	The number of planned or unplanned interruptions experienced by the customer over the useful life of a product.
Shareholder Metrics	
Inventory Turns	The cost of goods sold divided by the average on-hand inventory.
PP&E Turns	The turnover ratio for property, plant, and equipment.
Days Sales Outstanding (DSO)	The average collection period or accounts receivable turnover measured in days.
Supply Chain Spending	Total spending associated with the entire supply chain.
Value Created Productivity	Revenue minus purchased (material/buyouts) per employee.
Business Metrics	
Forecast Accuracy	Ability to achieve a predictable product/service demand forecast.
Cumulative Cycle Time (CCT)	The cumulative external and internal lead time to acquire material and build a shippable product assuming no inventory in pipeline.
Time to Volume (TTV)	Total time in weeks from published product concept document to volume availability of products/services.
Break Even Time (BET)	Total time in weeks from published product concept document to when profit is equal to investment.
Total Defects per Unit (TDU)	Number of defects discovered at the time of customer installation, (i.e., hardware/software, short-ships, mis-ships)

measures. Behind each of these performance measures are the various enablers and causals (drivers) which are analyzed depending on the performance of the metric in question.

Discussion. The primary strength of Digital's supply chain measurement system is its holistic approach. This system-wide view makes the system *comprehensive, causally oriented*, and *horizontally integrated*. The system is *comprehensive* in that it includes all of the stakeholders in the process: the customers, the shareholders, and internal managers. The customer oriented metrics are externally oriented and address how well Digital is meeting its customers' implicit and explicit needs. The shareholder metrics are all financial measures which capture the short-term costs. The internal process metrics are time metrics and cover the entire production and distribution process.

The system is *causally oriented* in that it makes good use of performance drivers in each of the perspectives. Because of Digital's market environment, the two primary ways that logistics can improve its competitive position is to (1) deliver new products to the market in sufficient quantities as quickly as possible and (2) minimize the problems that the customers face. These are the primary drivers for Digital's long-term success and the measurement system tracks both of these aspects. The *Business Perspective* metrics are almost exclusively time based metrics for introducing new products. Digital faces a ramp up demand pattern for every new product entry so the metrics try to measure how well that can be accomplished. The predictability, annual rate of events, and total

The primary strength of Digital's supply chain measurement system is its holistic approach.

defects per unit metrics each capture a different aspect of the quality of delivered product.

The system's *horizontal integration* shows itself in four ways. First, the system is expandable in that the metrics can also include other players in the supply chain. For example, the total cycle time for the entire process can be used in the *responsiveness* metric. Second, the metrics are focused on meeting customer expectations with two types of measures being used for this purpose: *predictability,* which captures how well Digital adheres to the negotiated standard, and *responsiveness,* which measures how close the delivery time is meeting the expected or desired levels. Third, the system encourages integration of activities. The *supply chain spending* metric in particular includes all costs for order fulfillment, material acquisition, inventory holding, and all other logistics related activities. This measure tends to break down a purely functional motivation and encourages more of a process view. Fourth, the system ties together all three types of flow going through the Supply Chain. *Responsiveness* ties together the information flow from the customer to the product flow going to the customer through the use of cycle time. The *days of sales outstanding* metric ties together the physical flow to the customers and the corresponding financial flow back to Digital.

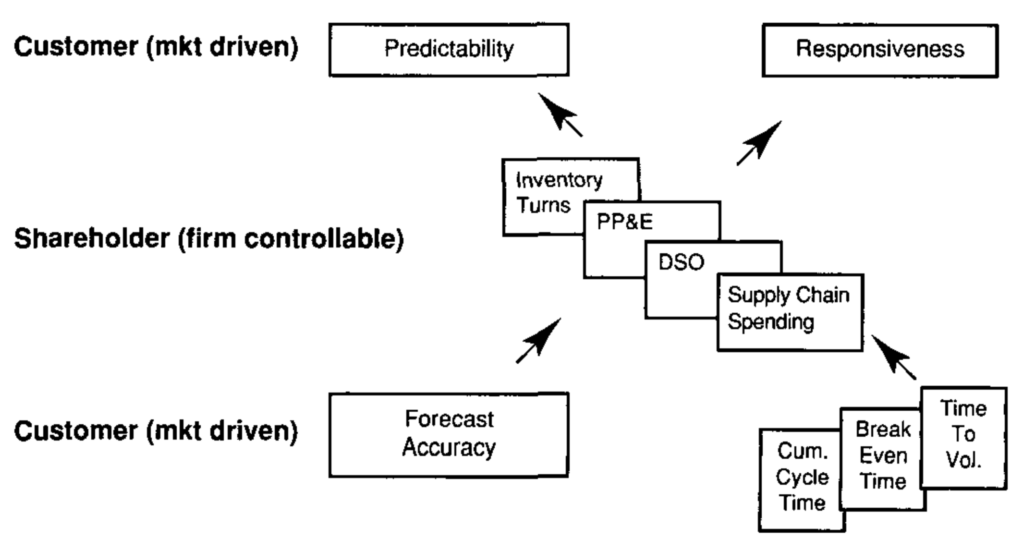
The primary weakness of the system is that the metrics do not extend all the way to the customer's location...

The measurement system addresses *internal comparability* by at least mapping the interrelationships between the metrics, as shown in Figure 3. Essentially, the business metrics are the drivers of the shareholder performance along with the market forces. The shareholder activities are all internally controlled by Digital and in turn drive the customer metrics of predictability and responsiveness. The ultimate idea is to be able to predict what, say, a 20% variability in forecast accuracy will do to the predictability and responsiveness of the operations.

The primary weakness of the system is that the metrics do not extend all the way to the customer's location which limits its *horizontal integration.* The location of these measures are at the point of last shipment from Digital and not from receipt by the customer. This means that the metrics are not tracking the uncertainty in the last leg of delivery from Digital to the customer. This is especially a problem since many shipments consist of components from different plants worldwide which are merged in-transit for a single delivery to the customer. This is a recognized problem that is currently being addressed.

In summary, the system has a strong supply chain focus which is easily expandable to include other players in the chain; matches actionable plans to the overall strategy by measuring both speed of

Figure 3
Schematic of Digital's Interactions Between Metrics



new product entry and customer satisfaction; and combines both short-term financial metrics and long-term physical metrics. The weakness of the system is in the details. The customer dial metrics for responsiveness and predictability currently end at Digital's dock. They should be extended to include the delivery of the product to the customer location, to include any bundled service requirements; a problem which is being currently addressed. A summary of the discussion is shown in Table 5.

Closure

While Goodyear and Digital are in dissimilar businesses with different products and customers, the two systems are similar in three respects. First, both systems are *comprehensive* in that they recognize and track performance across multiple dimensions. Each of the dimensions, and supporting metrics, was selected due to its importance to the company's overall operations and strategic position. Second, both systems are generally *causally oriented* in that they use many nonfinancial measures within their systems. The nonfinancial metrics were recognized by both systems as being the drivers of future performance. Third, they have both lessened *horizontal integration* by measuring performance at their own location rather than at their customer's. Both of the measurement systems' effectiveness measures currently only track performance up to the last point of shipment from their own facilities.

As expected, though, there are several differences between the two systems. First, the two systems differ due to different managerial objectives. Goodyear's system is designed to help higher management quickly assess the performance of the distribution of tires in the renewal channel and is therefore "DC" focused. Digital's system, on the other hand, is designed to measure the performance of distributing new products extremely quickly to various customers. It was designed to be used to measure supply chain performance and includes many service oriented metrics.

Second, the companies have different products. Goodyear's products are similar looking bulky items which require a significant amount of handling involving direct labor, thus explaining the need for a separate human resources dimension and the inclusion of a special metric to catch any mispicking. For Digital, the product includes a significant service component and therefore metrics such as the annual rate of events and total defects per unit are applicable.

Finally, the companies serve different markets. Goodyear is primarily distributing tires to dealers on a order-to-stock basis. While new tires are introduced periodically, the market is relatively stable, from the logistics perspective. The primary metrics,

As expected, though, there are several differences...

***...Goodyear and Digital...systems are similar in three respects...both systems are* comprehensive*...are generally* causally oriented*...have both lessened* horizontal integration...**

Table 5
Summary of Evaluation of Digital's Supply Chain Performance Measurement System

	Measurement System Criteria
Comprehensive	This system incorporates the three major performance dimensions, customer, internal, and financial.
Causally Oriented	The system is driver oriented in its selection of metrics within each performance dimension.
Vertically Integrated	These metrics appear to be directly applicable to lower levels of management.
Horizontally Integrated	The system is horizontally integrated in that most of the metrics are expandable along the supply chain. This is its primary strength although some of the individual metrics are limiting.
Internally Comparable	The interrelations between the different performance dimensions are recognized and mapped out if not formalized for quantifiable trade-offs analysis.
Useful	The system is action oriented and is very understandable.

then, are availability measures. Digital, on the other hand, is constantly introducing new products to market so that the speed with which the logistics system can deliver the product is critical. Therefore, the measurement system captures this aspect with a series of time metrics, such as cumulative cycle time, time to volume, and break-even time.

While each of the systems work well within their own environment, they would not transfer to the other company very well. This implies that while there are certain common points that can be shared by most measurement systems, there will always be situation specific characteristics.

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