Payoff
Global manufacturers must leverage their IS capability and information assets in ways that can create cost or competitive advantage and distinctive services across the supply chain, up to and including the customer. IS needs to create the necessary computing infrastructure and adopt an organizational model that reflects its new primary product: information delivery. This article addresses some of the fundamental data integration and architectural issues related to global manufacturing and information delivery.

Problems Addressed
The two most important responsibilities of leadership are to establish a vision or strategy for the organization and to put in place the systems, processes, and structures that enable the organization to progressively achieve that vision. One of the structures used by manufacturers to create competitive advantage is integrated information systems. Competitive advantage, including cost and differentiation, can be won or lost by marginal differences in the speed, accuracy, and comprehensive nature of information being delivered to decision makers.

An organization's competence in timely decision support capabilities has been given impetus by the total quality movement; the Malcolm Baldrige criteria state that “the ability to access and act on timely, reliable business data is requisite to the achievement of quantitative continual improvement in the delivery of products and services.” 105

Michael Porter has described the importance of horizontal strategy as the interrelationship between business units. Integrated information and control systems support horizontal strategy, enabling independent business units to share key product and process information along the whole supply chain.

Horizontal Business Integration Strategy
Manufacturers are providing increased service levels in response to competitive pressure and to create differentiation in product offerings. One trend is toward smaller, custom lot sizes on the part of the process manufacturer and custom product configurations on the part of the discrete component manufacturer.

As manufacturing assumes these higher levels of service, the strategic model of the manufacturing organization is moving toward a professional context, in which the operating work of an organization is dominated by skilled workers who use procedures that though difficult to learn are well defined.106 In this model, empowered workers are given greater decision latitude. In other words, with increased automation of the manufacturing processes, the nature of the work in the plant or factory shifts from manually effecting the independent processes to using information systems in support of

105 Malcolm Baldrige National Quality Award, US Department of Commerce and the National Institute of Standards and Technology, Gaithersburg MD 20899.
customer-driven operating objectives related to production. The empowered worker equipped with business operating objectives makes decisions using information that previously was the purview of manufacturing management. Information systems, integrated with factory automation systems, therefore enable both differentiation and flatter organizational structures.

Compared with the conventional machine concept of the manufacturing organization, empowered or high-performance work teams typify a more people-centered, organic culture. This new manufacturing organization depends on high-speed access to high-quality information. For example, Total Quality Management prescribes the use of statistical quality control (SQC) techniques. Manufacturers use Statistical Quality Control techniques software to help workers process the sheer quantity of data required by the application of SQC principles in manufacturing, further illustrating the affinity between strategy, organization, and information technology.

The IS organization within the global manufacturing enterprise must understand the impact organizational strategy has on the information technology (IT) infrastructure. Furthermore, it must determine and create the optimum IT architecture to best support a horizontal business integration strategy.

Differentiating Information System Products and Services

Historically, IS has delivered custom computer applications to business functions to improve effectiveness and reduce cost. System projects were justified on their standalone return on investment. The IS management structure reflected project team independence and aligned applications development teams with their respective customers (i.e., manufacturing, finance, or distribution). This approach to systems development avoided the long-term need to integrate data between applications. Viewed separately, each system met its functional objective. Viewed collectively, they presented a set of conflicting interfaces and incompatible information, thereby constraining a horizontal business integration strategy.

As businesses flatten their organizations, their dependence on integrated information flow across worldwide boundaries increases. The IS organization must find ways to remove the functional and technical incompatibilities of existing computer systems that are barriers to business-centric information access.

Trends in Manufacturing

More business managers recognize that information-related service extensions to their product/service mix can effect their companies' ability to compete favorably in international markets. They are also beginning to recognize that existing computer systems were designed in a way that is inconsistent with the view of information as an asset to be managed by the corporation, which has led to concerns about the return on investment for older systems.

Plant-level information systems, once the domain of process control engineers and production personnel, are being drawn into the scope of the IS function from the standpoint of integrating the operational data in these systems with horizontal supply-chain business strategy. The span of the IS organization's responsibility may expand to include multiple operational (e.g., manufacturing) systems from which enterprise information is collected and delivered. The charter of IS becomes focused on assimilating and combining manufacturing-process data with other forms of business data to enhance the quality of customer service, to support integrated operations objectives, and to provide value-added decision support across the corporation.
Quantity of Manufacturing Data

Information systems are pervasive across the manufacturing supply chain. The entire manufacturing supply chain uses information, but the epicenter of information technology in a modern industrial manufacturing company usually exists at the manufacturing plant site. Here, a variety of systems, using data at different levels of abstraction, are employed to control manufacturing processes, provide decision support to operations, and perform planning functions such as those offered by MRPII (material requirements planning) systems.

The problem of functionally integrating manufacturing software applications is exacerbated by the total volume of data employed in manufacturing. In the case of the process/batch manufacturer who employs process control systems, extensive quantities of process data may exist within the process control applications. Most of that data is needed by other parts of the manufacturing organization. It is common, for example, for a process manufacturing plant to generate 8 to 10 million pieces of information every 24 hours.

A central concern when manufacturing-process data is integrated into enterprisewide information systems is the requisite changes necessary to derive information from elemental process data. For example, a Fortune 100 diversified chemical company needs to maintain a complete history for each lot or batch of material made, including details of the processes used to make any given batch. A maker of an automobile safety device needs similar detailed information for each discrete component and assembly produced. In addition, the customer, the automotive industry, and proper business practice all specify that the detailed information be maintained indefinitely and be available on demand during the anticipated 20-year life of the product.

Nature of Manufacturing Data

The problems outlined in each of these situations can be understood when the nature of manufacturing data itself is examined. Exhibit 1 identifies four categories of data that exist in manufacturing:

- Derived data needed for longer-term business decision support.
- Transaction-driven, product-oriented data.
- Event-driven, operations-oriented data.
- Real-time, process-oriented data.

Manufacturing Data Framework
The columns of Exhibit 1 contrast the key attributes of these different data types. Non-site-specific positioning of derived data is critical to successful horizontal business integration for the multisite manufacturing enterprise.

Process data possesses the lowest level of integration in manufacturing, whereas decision support data has usually been integrated or summarized to afford the user a basis for broad business and planning decisions. These two extremes can be illustrated by considering the questions the business user of manufacturing data might ask as compared with those asked by a process engineer concerned about the problem of manufacturing process optimization.

Business users of manufacturing data might want to know about the yield for a given product manufactured at all sites during the previous month. A typical process engineer might inquire about the historical trend of temperature for one or more tag (i.e., input/output) values, related to a particular piece of equipment or process. Both questions have equal relevance and potential merit, but they are fundamentally different, being based on the type of data needed to render a valid response.

The process-related question requires access to manufacturing(i.e., process control) data at its lowest atomic level. The product yield question requires access to data stored at a higher level of abstraction. Process data such as lot/batch yield must be collected and derived uniformly into a value for product yield at each site. This type of query represents a significant change in the level of abstraction and integration of the data across multiple plant sites.

The operations data presented at the middle levels of Exhibit 1 reflects the transformation of data from process (tag) to subject(table). An operations data base often provides a repository for manufacturing data that is clearly outside the process domain but is still necessary for manufacturing. Operating conditions, procedures, recipes, and specifications, organized by product, equipment/cell/area, or manufacturing team, are often candidates for operations data. If Material Requirements Planning is employed, the operations information data base is also often used to provide the MRP system order-operations as they are completed by product, line, or plant.

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Data-Driven Manufacturing Application Framework

Past efforts to computerize manufacturing focused on the automation of isolated process steps or organizational functions. The success of the global manufacturing enterprise depends on new application architectures, predicated on data integration, and the availability of derived production data for use in multisite business decision support. Using the categories of manufacturing data from Exhibit 1, a data-driven application framework can be constructed for a typical manufacturing site (see Exhibit 2). This framework takes advantage of the existing differences in data, provides for the horizontal separation of multiple manufacturing process steps, and recognizes the need for operational integration. The upper level in this manufacturing site application framework supports the business need for horizontally integrated, multisite production information access.

Data-Driven Manufacturing Application Framework

Adoption of a consistent manufacturing site application framework both enables multisite integration and presents a major cost-reduction opportunity. The lack of a consistent framework for site applications all too often results in unique site applications requiring expensive life cycle support. Use of a consistent framework enhances the prospects of multisite applications development (or commercial purchase), which significantly lowers life cycle support cost.

Effective Information Delivery

In view of the strategic use of IT and the vast quantity of manufacturing data now available, what should be the product of the IS organization? What should be the role of IS in the world-class manufacturing organization?

The manufacturing IS organization is required to reduce total cost of ownership of software systems, reduce lead times, increase flexibility of developed applications, deliver integrated (i.e., customer, supplier, and internal manufacturing) information to a wide variety of users across the enterprise, and develop and acquire applications suitable for multiple sites. The manner in which these conventional business objectives and their implied information needs are provided must improve for the manufacturer seeking integrated information and control systems.

Information collection and delivery is replacing applications development as the IS organization's prime responsibility. The advent of consistent manufacturing site application frameworks and the growing availability of commercial applications to satisfy operational needs can reduce, over time, the IS role in the development and support of operational applications. As a result, IS can focus on the development and support of a new infrastructural layer of decision data services and networks built above the existing base of manufacturing site and centralized order entry/product distribution systems.

Infrastructure for Worldwide Decision Support

This infrastructural layer is designed to collect and position the requisite information for horizontal supply-chain integration and worldwide decision support. William Inmon's unified data architecture with data warehouses holding decision support information separate from operational systems is gaining acceptance in manufacturing and
nonmanufacturing industries alike. The IS organization's prime responsibility is to implement and maintain this secure worldwide decision support infrastructure (see 3 and 4) and to provide business with effective information access and delivery mechanisms.

Data Delivery Architecture

Global Scope

The IS organizational model have evolved so far to optimize its traditional primary product: custom applications development. To accomplish worldwide information delivery, IS must adopt an organizational model that reflects its new primary product. As the IS organization changes from a custom manufacturer to a product distributor, with enterprise information as its essential product, the central focus of IS becomes information supply, inventory, regional warehouses, and business delivery mechanisms. The responsibility for this nonoperational data storage, structure, and content must be separated from applications development and controlled centrally or regionally, driven by the need for data integration, end-user data access, and enterprise-wide data integrity (see Exhibit 5). Distributed information storage and access mechanisms, predicated on the use of client/server technologies, can be implemented to insulate both the business users and Decision Support System developers from the incompatibilities of existing operational applications.

The Path to IS Renewal

New or reengineered operational systems are required to pass selected data from manufacturing sites and centralized order entry/product distribution operational systems to the infrastructure layer, thereby taking advantage of the infrastructure's ability to provide data to decision support applications. New operational systems can be downsized and optimized to best meet the immediate operational tasks. History, nonoperational analysis, and reporting could be accomplished as extensions of the infrastructure layer using commercially available analysis tools. Such a strategy allows users to select analysis tools according to their own business needs, with IS ensuring the integrity of the data managed within the infrastructure layer.

Delivery Teams

A consistent set of development policies, principles, methods, and tools is needed to govern the secure development and delivery of information products and services. Online metrics relating to the performance of the infrastructure layer need to be made available to determine who is using information, as well as when, why, and where information is being used. A single (i.e., logical) decision support environment can provide insulation from underlying hardware and operating system incompatibilities. Decision support applications can be accomplished as a unified effort by IS or others, independent of the facilities or physical location of the developer.

A new IS business-focused organizational model emerges in which internal technical support teams assume the responsibility to design, build, and support the infrastructure

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layer. Radiating from the core are information delivery teams working directly with the businesses to identify information needs and ensure information delivery. Exhibit 6 details the relationships among the different members of the business-focused information delivery team. Exhibit 7 shows the overall organizational model for optimizing information delivery.

**Business-Focused Delivery Team**

**Business-Focused Organizational Model**

**Recommended Course of Action**

The actual steps required to move an IS organization toward the described information delivery paradigm depend on current IS business practice and how quickly the IS and business cultures can accept change. Although the individual paths forward will differ, the overall goal is to establish sustainable change in both the IS technology and the people processes.

**Organize Around Information Delivery**

If the IS function is to be a provider of information as opposed to a provider of automation, then change is a prerequisite. The IS culture can begin by defining its purpose as that of empowering its user community through access to information.

Existing IS organizational structures that optimize custom applications development should gradually be replaced with structures promoting cross-application integration. Decision support capability should be removed as a task of individual applications development teams and organized as an enterprisewide infrastructural activity. Employee recognition and reward mechanisms must be redesigned to reinforce and sustain these new IS directions.

**Develop and Implement an Enterprisewide Architecture**

The plant sites of the global manufacturer are often littered with locally optimized IT solutions that defy integration into a multisite supply-chain strategy. The standalone nature of these solutions reflects the fact that no shared business rules or IT framework exists to provide the technical integration ground rules.

An essential IS path forward is the establishment of the architectural framework that provides a consistent technical context for horizontal business integration strategy. This framework should provide specific guidance for both existing and proposed applications, technology, and data. Data is not only a valid architectural consideration, it is fundamental to establishing integrated information delivery mechanisms. The data models resulting from data architecture development become the product catalogs for the IS function's information delivery business.

Information strategic planning (ISP) offers a valid approach to designing the overall enterprise architecture. The deficiency in information engineering has been a lack of recognition of the fundamental differences and uses in manufacturing data at different levels in the architecture. Exhibits 1 and 2 reflect these differences and their implications.
for manufacturing systems. Exhibits 3 and 4 reflect the logical placement of the data warehouses in the global manufacturing architecture. The use of encyclopedia-based Computer-Aided Software Engineering technology is strongly recommended in the development of the enterprisewide architecture. The distributed nature of this technology allows IS to both automate and share reusable software assets while teaming across geographical boundaries.

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