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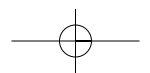
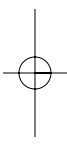
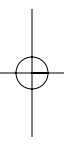
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# Interfaces and Decisions in an Enterprise

*Structuring the value-adding activities that make an organization competitive in the dimensions of innovation, rapid-response, scope, and quality. Understanding the roles of information and material-flow in creating interfaces among functions in terms of decentralized coordination.*



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**CHAPTER**

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**1**

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**Domain and Process Views  
of an Enterprise****1.1 INTRODUCTION**

How a business unit is structured and organized has major implications for its competitiveness. Competitive advantage primarily comprises two elements: the values a company can create for its customers (in excess of the cost of creating the value) and innovations. While value to the customer creates an immediate competitive advantage to the firm, innovations provide sustenance to this advantage. Value created for a customer is a multi-dimensional entity comprising price, variety, quality, and response time, among other factors.

To add value to a product, it must be put through a series of activities (process), from acquisition of raw material to distribution of the product to retail stores. The sequence of activities has variously been called a value chain (Porter 1985), commercial chain (Hayes and Wheelwright 1984), and supply chain. While the models differ in detail, all of the above chains advocate clusters of activities, usually called functions, joined together by a linking mechanism. We call this the domain view of the enterprise, where each function is an individual domain. Proponents of business process reengineering (BPR) strongly argue for a process view of the enterprise, where the emphasis is on individual processes rather than on functions (Davenport 1993). This is also known as the horizontal view.

## 1.2 DOMAIN VIEW

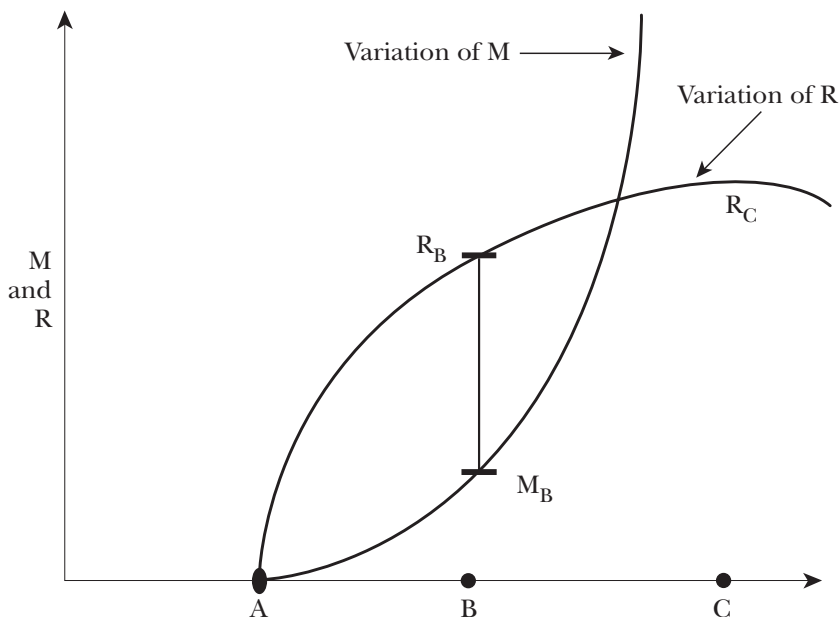
The domain view, where activities are organized into functions, is the more traditional view. This view, in all likelihood, has evolved from the need to differentiate one function from another because of their inherent dissimilarities. In the marketing and manufacturing domains the factors causing differentiation would be expectations (profit and sales vs. cost and timely production), complexities (capacity utilization and sales forecast vs. cost of capacity), managerial orientation (customer focus vs. plant focus), and organizational culture (impressionist vs. craftsman). Thus the nature of tasks in any two functions may require totally different sets of skills, resources, and organization culture. As the company grows, these functions evolve to assume their own distinct identities. Managers in the manufacturing domain, for example, may know nothing about brand management, advertising, promotion, sales, channels, and pricing. Marketing managers likewise may be ignorant of manufacturing technology, process plans, machine capabilities, maintenance, and in-process inventory.

Such differences may become a major impediment to the firm in achieving competitive advantage. If, for example, customers demand greater product variety and/or more frequent delivery, the marketing domain would need manufacturing to agree to broaden product mix and/or to implement a just-in-time (JIT) type of production schedule. In the absence of meaningful linkages among functions, such problems become major sources of conflict. Reducing the number of domains would be one way of minimizing interdomain conflict.

Malone and Rockart (1991) report how Frito-Lay reduced organization layers by using technology to increase coordination. With a sales force of 10,000, a hierarchical organization structure would have required many layers to enable communication and coordination between the salespeople and the management. Instead, each salesperson was given a handheld computer to record sales data on 200 grocery products. The sales data is transmitted daily to a central computer, which sends back information on changes in product pricing and promotion to the salespeople. A similar application of computer technology (laptops) was reported by Hewlett-Packard, which used it to provide information to salespeople during customer meetings (Berger, Angiolillo, and Mason 1987). Time spent in meetings decreased by 46%, travel time was cut by 13%, and sales rose by 10%.

The linkages between any two functions are meaningful if they lead to a maximization of the surplus for the two units together. Consider again marketing and manufacturing functions. Let the total revenue from the current sales of products be denoted by  $R_0$ , and the corresponding manufacturing cost by  $M_0$ , so that the surplus is  $R_0 - M_0$ . Assume now that the revenue can be increased by  $R$  units by providing a greater product variety to the customers, but that the corresponding increase in manufacturing cost would be  $M$ . Let  $M$  and  $R$  vary with product variety, as shown in Figure 1.1.

It is obvious that the marketing function would like to increase the value of  $R$  up to  $R_C$ , corresponding to the product variety denoted by point  $C$  in Figure 1.1, and the manufacturing function would like to hold the value of  $M$  at  $M_0$ , at point  $A$ . A meaningful relationship, on the other hand, would assess the shapes of the  $M$  and  $R$  curves and establish that the maximum surplus of  $R_0 + R_B - (M_0 + M_B)$  is obtained at point  $B$ . Assessment



**FIGURE 1.1: VARIATION OF REVENUE AND COST**

of the shapes of  $R$  and  $M$  curves becomes a harder proposition when other dimensions of competitive advantage such as quality, delivery lead time, and life cycle are included in this consideration.

It is clear that although a linkage between marketing and manufacturing functions maximizes the firm's surplus (at point  $B$ ), both marketing and manufacturing incur costs. The cost to manufacturing is  $M_B - M_0$ , and the cost to marketing is  $R_C - R_B$ . Porter (1985) discusses several types of costs in creating relationships between different business units. As pointed out above, similar costs are also incurred by different functions within a business unit. These costs, as in Porter, can be summarized as cost of compromise, cost of coordination, and cost of inflexibility.

Cost of compromise results when neither function in a linkage is allowed to achieve its own optimum. In Figure 1.1 we observed how both marketing and manufacturing functions incur cost when required to compromise on product variety. Consider a second example, delivery lead time. Increasing the frequency of product delivery to the customer decreases the customer's inventory-related costs. The customer would therefore be willing to pay more for the product and/or buy more annually. The potential of increased revenue would motivate the marketing function to increase delivery frequency until the marginal marketing surplus becomes negative (similar to point  $C$  in Figure 1.1). The increase in delivery frequency, however, would increase the annual cost of machine setups, or the manufacturer would have to invest heavily in new processes and technology to implement a JIT-type production schedule. Through an appropriate form of linkage, a compromise on frequency of delivery can be reached (similar to point  $B$  in Figure 1.1) that would have cost implications for marketing (as point  $B$  is lower than point  $C$ ) and for manufacturing (as point  $B$  is higher than point  $A$ ). Another example of compromise would be in planning product promotions and production scheduling. Marketing functions may carry out special promotions of a few select products that may be under threat from competitors. Most such promotions are time bound projects in which sales increase significantly but with only a moderate increase in net revenues. After the promotion ends, sales are scaled back but (typically) not as far back as before the promotion, creating a longer-term advantage in revenue. The sudden short-term surge in sales, before reaching a new steady state, requires manufacturing to build up inventory of the product or to contract for additional manufacturing capacity. This may be very costly to the firm. There will therefore

be a compromise that would constrain marketing in terms of the frequency of promotions and require manufacturing to incur additional cost to satisfy the periodic surges in sales.

Cost of coordination results from the need to have the parts of the linked system perform in unison. Consider the case of product modification. From time to time marketing may come up with requests for product modifications, based on feedback from customers. Such a modified product (since it is initiated by the customers) has a high demand and hence a high revenue potential. A modified product differs from the original product in only a few aspects. Many of the components between the modified and old products may be common, but there may also exist a significant number of components that are not common. An instant and total switch to the modified product would cause major upheavals for manufacturing for several reasons. First, a product is usually committed to customers for several periods in advance, and they may not always agree to switch to the modified product. Second, since commitments are made for component production and/or purchase several periods in advance of assembly of the product, an instant switch to the modified product would make the non-common components obsolete, or a heavy penalty would have to be paid to the suppliers for contract violation. To minimize such coordination-related costs, the manufacturing function may prefer to switch to the modified product in stages, gradually reducing the quantity of the old product and increasing the quantity of the modified product. These quantities need to be phased in carefully by reassigning the common components to the modified product and minimizing the obsolescence of the noncommon components.

Boeing faced a similar problem in the early eighties (Garvin 1991) when it planned to modify its 767 aircraft design from a three-person cockpit to a two-person cockpit, preferred by some airlines. For the 30 aircraft that would be affected, Boeing estimated that it would require 2 million hours of additional labor. The redesign also required over 12,000 modifications related to seating arrangement, carpet color, and wiring and part changes. Such modifications needed to be phased in because of their technological dependencies. Though the costs of coordination and new material were significant, the potential for long-term revenue increase was also very high.

Finally, cost of inflexibility results from the fact that the cost of making changes in one function will be very high if that function is coupled tightly

with several others. The impact of changes in one function ripple through other functions and may become amplified in the process. Toyota's supply chain is based on small "mom-and-pop" suppliers several layers down the chain (supplier's supplier's supplier, etc.). Even a small change in the final product can cause havoc for these tiny suppliers, who may depend on Toyota's business for almost 100% of their operations.

It should be clear from the foregoing discussion that well-designed linkages help interface one domain (manufacturing) with another (marketing). It is also obvious that not all activities in marketing need interfacing with manufacturing. For example, shelf management at a retail store (for the firm's products) may not have a significant effect on how the products are manufactured. Similarly, whether or not computer-aided design (CAD) is used for engineering design may not have a significant effect on the way distribution channels are managed by marketing. There is, however, a set of activities that significantly impact both manufacturing and marketing. We examine some of them to understand the nature of interface required. Shapiro (1977) and Montgomery and Hausman (1986) have also outlined the nature of this conflict.

### **Activities at the Interface**

The activities that appear to have most impact across the interface between marketing and manufacturing are product design, quality assurance, demand and capacity management, inventory holding, supply chain, production scheduling, and costing.

#### **Product Design**

Because of the increasing importance of two factors—decreasing product life cycles and shortening time to market—product design is assuming strategic importance. It is a given that marketing people would want products to mean all things to all people (Shapiro 1977). However, since customer preferences and customer ability to pay vary widely, and since customers appreciate variety, with emphasis on new products, it may not be cost-effective to try to satisfy all customers in all market segments at all times. Increasing product variety requires a larger number of unique components to be designed and manufactured, increasing cost. Modular prod-

uct design increases component sharing, but it may also reduce product variety to a less-than-desirable level for customers. Flexible manufacturing equipment can produce a wide range of components on the same machine, but the cost of designing and implementing a flexible manufacturing system (including personnel training) may be very high. Similarly, to reduce the time to market, product development time must be reduced. One way of doing that is to overlap (in parallel) development activities such as prototyping and testing, which would otherwise be done sequentially. Overlapping such activities can be very risky, however, as a design error found in one test may require all other tests, done in parallel, to be repeated.

An application of product design to reduce time to market of single-use 35 mm cameras is reported by Kodak, who used a well-structured database and a computer-aided procedure to frequently exchange design drawings among different functions (Davenport 1993). This transformed a sequential design process into one where components could be designed in parallel.

### **Quality Assurance**

There are several dimensions of product quality (Garvin 1984), but the two major dimensions are conformance quality and performance quality. Market share can be increased (albeit in different segments) by improving conformance quality (practiced by Japanese companies) or by strengthening performance quality (practiced by German companies such as BMW). To enhance performance, it is crucial that emphasis be placed on technology innovation and its incorporation in product design. This requires product designs to be modified as and when new technology appears. In the case of BMW (Pisano 1996) this has meant that product designs could not be frozen even at advanced prototyping stages, and so expensive modifications in manufacturing processes were required even during production ramp-up. This ensures the latest technology in products, but the time to market may become long and uncertain, and the cost of product development could be high. Japanese companies, on the other hand, aim at conformance quality. They meticulously practice freezing designs at a certain point, so any new technology innovations beyond those time fences are left to be incorporated in a future modification. During prototyping they lay emphasis on process simplification, appropriate material use, and

so on, so that conformance quality can be improved. The strategy (performance or conformance) to be followed obviously depends on the market segments the products are targeted to.

Linking product warranty with product quality is a vexing issue. Product warranty may be perceived as a substitute for product quality by many customers. The trade-off between the cost of servicing a product warranty and the cost of improving product quality must therefore be incorporated in product design and coordinated with the design specifications of the warranty (such as length of warranty for each component or assembly covered, group warranty, and encouraging customer maintenance of products).

### **Demand and Production Capacity**

Uneven sales from one period to another are a fact of life in marketing. If production quantities were synchronized exactly with sales, manufacturing would have a severe capacity management problem on its hands. Capacity cannot be increased at short notice, as construction of new buildings, acquisition and commissioning of complex machinery, and training of personnel take a considerable amount of time.

The type of capacity to be added and its location will have a profound impact on competitiveness. The facility can be focused or it can be flexible. It can be automated or it can be manual. Chakravarty (1987) describes possible interactions of facility types with market dimensions (related to customer service) and control dimensions (related to software control) and suggests possible paths of upgrading the facility as market conditions change. An automated mass-production assembly line is an extreme case of facility focus. This would be appropriate for cost-based competition in a mature industry such as textiles or paper. For manufacturers in industries such as electronics and auto, a flexible manufacturing system (FMS) would be very desirable. Allis Chalmers Company of Milwaukee was perhaps the first to implement a flexible manufacturing system, in the 1970s. However, the farm equipment industry at that time was stagnant and could not sustain product innovations. Allis Chalmers was unable to use its flexibility for market advantage, and the company folded in the mid 1980s, as the investment in its FMS was very high. Allis Chalmers' market analysis, obviously, was far from satisfactory. Many companies in the United States have

rushed headlong to invest in FMS but have ended up using it for dedicated mass production with disastrous results (Jaikumar 1986). In Japan, on the other hand, companies have carefully acquired FMS and have exploited its flexibility to maximum advantage. Naik and Chakravarty (1992) discuss a framework for linking the strategic priorities of the company (low cost, product differentiation, mass customization, etc.) to the choice of a manufacturing system. They use an adaptation of a technique called quality function deployment (Hauser and Clausing 1988), to create multidimensional linkages layer by layer (for several layers), and use a qualitative model for choosing an appropriate set of linkages.

Demand management, where customer demands are shifted from one time period to another, using financial or other incentives is another way of reducing cost of capacity. Service industries such as electrical utilities, telephone companies, airlines, and doctors' clinics are prime examples. This approach can be tried when providing flexibility, in a manufacturing or service capacity, is either not feasible or is prohibitively expensive. It will obviously be optimal to try to use a mix of capacity flexibility and demand management.

Outsourcing manufacturing or service is a third approach that has become popular, as it frees the company from the headaches of managing a production facility (especially for those companies that do not possess core competency in the production function). The third-party service, provided by firms that combine orders from different companies, can better exploit economies of scale. While the cost advantage of outsourcing is not in doubt, the optimal level of outsourcing may not be apparent. Hayes and Wheelwright (1984) address the issue by asking where on the commercial chain a company should position itself. A simplistic response would obviously be to retain core competencies and outsource the rest. But what about developing new competencies in view of market opportunities (Hamel and Prahalad 1989)? The point is that outsourcing policy should be carefully examined in terms of the company's core competencies and emerging market opportunities.

## **Inventory**

Inventories build up in a system for two main reasons: fluctuations in customer demand and cost of setups in the system. Substantial labor and

material costs are involved in changing over a machine to produce a different product. A setup cost is also incurred in preparing and processing a purchase order and inspecting the goods delivered.

If setup costs in the system are high, the number of times (per week) a machine is set up for a product change and/or the number of purchase orders (per week) will have to be kept low. The production quantity per setup and/or the quantity per purchase order will have to be large to cover demand for the longer duration between setups. This will increase the average inventory (cycle inventory) carried in the system. Without sufficient inventory in the system, customers would experience shortages toward the end of a production cycle. Reduction in setup time, therefore, is an important issue in reducing the conflict between manufacturing and marketing and propelling the system toward JIT.

To safeguard against fluctuations in demand, most firms like to carry a safety stock over and above the cycle inventory as described above. The size of the safety stock will, of course, depend upon the extent of uncertainty in demand and the degree of customer service planned. Note that if production and/or purchases are done just in time, both cycle and safety inventories will be driven to zero simultaneously. This may not be achievable, however, for several reasons. If demand fluctuations are high, the cost of capacity fluctuation induced by JIT may be too high. To avoid up-and-down capacity variations, most companies that have implemented JIT allow excess capacities. This, in effect, substitutes the cost of excess capacity for the cost of safety inventory. Before implementing JIT, therefore, it is necessary to reduce setup time and cost by completely reengineering the setup process (Monden 1983), which may also require investment in new technology used in the setup process, production process, and product design. Such investments can be substantial, as experienced by companies such as Harley-Davidson and Johnson Controls (Mishina 1993) in their switch to JIT from MRP (materials requirement planning). Investing in a flexible manufacturing system is an alternative to reengineering the setup process, as in a flexible system manufacturing can be switched from one product to another without a substantial setup cost. Irrespective of whether the setup process is reengineered or flexible manufacturing is used, it may never be possible to drive the setup cost to absolute zero. Hence inventory carried in the system may not be totally eliminated, as evidenced by the number of kanban cards ( $>1$ ) circulating in any JIT system. For this reason, Japanese companies such as Toyota try to maintain level

production but use a mix of model types, carefully determined, to match variations in demand (Miltenburg 1989).

Product family is a concept that can be used to reduce setups in the system. Products that are similar in terms of setup needs such as tool requirements, unit costs, and demand rates are grouped together. The entire group of products is manufactured together without requiring a major setup of the machine (Goyal 1974; Chakravarty 1984a). Chakravarty (1984b) shows how such groups can be used to obtain price discounts based on the total value of a purchase. For products with demand fluctuations, however, determination of such groups becomes very complex.

Another issue is the trade-off between carrying cost and lead time. When sales are uneven, sales personnel would like to carry an inventory of finished goods to maximize the probability of making a delivery to a customer on time. Because of the value-added effect, which can be substantial in a high-tech or complex product, manufacturers like to hold inventories of raw material and components rather than finished goods. While this reduces inventory-carrying costs, customer service may suffer, as the length of manufacturing lead time, from component manufacture to final assembly, may be substantial. A mixed strategy of holding inventory at different levels of the bill of material (BOM) and using some manufacturing flexibility may be optimum.

## Supply Chain

If customers require rapid response for a wide variety of products, the effectiveness of a supply chain from plant to customer becomes very important. Major issues are configuration of the supply chain and structure of the supply contract. While a centralized manufacturing plant requires the least investment, it may also be the most unreliable from the point of delivering goods on time to different locations, and the cost of distribution can be extremely high. How many plants to have and where to locate them, obviously, would depend upon the structure of the supply contract. In designing such a contract, the trade-offs among delivery-time window, unit price, plant proximity to customer, and inventory holding policy must be exploited. Penalties for cancellation of orders by a customer, order revision, and the supplier's tardiness must also be weighed in. While marketing would like to minimize costs and risks involved in the distribution (supply) chain by having plants in all major locations, manufacturing

would attempt to minimize the cost of total investment in plants. Design of an efficient supply chain may be totally overlooked in this process of negotiating a compromise between the marketing and manufacturing domains.

It is not cost-effective to design a quick-response supply chain for a commodity product such as toothpaste. On the other hand, for products with high value added and/or short life cycles, such as cars and electronic goods (including PCs), supply chains must be designed to be responsive and fast (Fisher 1997). Federal Express, in an industry with short delivery cycle requirements, has developed an elaborate computer-based supply chain that has received high acclaim (Blackmon 1996). Tracking products by time and location is an important element of control in a supply chain of this kind. To respond to customer queries about package status, Federal Express uses a method in which each package is scanned several times while in transport. Customers can now tap into the company's central computer in Memphis to build Web sites to promote their own products. It would also allow online transactions.

To avoid bottlenecks and to eliminate less promising drugs early, Johnson and Johnson has developed a database to track the progress of drugs through research and development cycles (Davenport 1993).

### **Production Scheduling**

To determine daily or weekly production quantities, most manufacturers use control systems that can be some form of MRP or JIT. While MRP maximizes capacity utilization, JIT is geared to satisfying individual customer orders. The three-way trade-off among capacity utilization, inventory holding, and customer service determines the appropriate control system. MRP is associated with a high cost of inventory and schedule inflexibility, and JIT can incur high capacity cost (due to unused capacity). The marketing function would naturally want to use JIT to maximize customer service, but the manufacturing function would like to use a hybrid of JIT and MRP to minimize the total cost.

At Bethlehem Steel, for example, the process of scheduling a customer order into the production schedule was extremely chaotic and inefficient. It led to customer dissatisfaction and sales force frustration, at one end, and high manufacturing cost, at the other. Bethlehem had to completely reengineer its scheduling process (Davenport 1993).

To maximize throughput and/or to minimize congestion on the shop

floor, dispatching rules that prioritize jobs to be processed on a machine are used. Such priority rules are based on a combination of factors such as processing time of the job, its due date, order of job arrival at the machine, and number of remaining processing steps. Rules such as priority by shortest processing time or priority by earliest due date will obviously vary in their impact on the system. To optimize the system, dispatching rules need to be selected dynamically based on the shop floor status. This requires an intelligence component to be built into shop floor scheduling. Artificial-intelligence approaches have been suggested that use decision trees (Shaw, Park, and Raman 1992; Naik 1995), data envelopment analysis (Chakravarty 1997), or neural nets (Cho and Wisk 1993) to make a selection for a given shop floor status from a given set of dispatching rules.

### **Costing**

The unit cost of a product is (usually) used as the base for determining unit price of the product. How overheads are allocated to products impacts the unit cost. Activity-based-costing (ABC) allocates overheads to products based on the extent of resources utilized by the product. While it is a big improvement from allocating overheads based on direct labor hours, it suffers from not being able to incorporate market-related concerns. Depending on the shapes of the price-demand curves of individual products, it may be possible to increase total profit if overhead allocations, different from that suggested by ABC, were permitted. The other issue is that ABC cannot be adapted easily to a flexible system, necessary in a market-responsive company. The problem lies in the fact that ABC does not permit multiple-allocation schemes for overhead. Consider, for example, a flexible system, where parts can be routed to more than one machine at any processing step. The total overhead allocated to a part will now be a function of its routing, which in turn will be a function of shop floor status (congestion, tool availability, machine breakdowns, etc.). Since the profit margin is determined on a product type and not on individual copies of the product, some kind of averaging of overhead allocation for different routings will have to be done.

## **1.3 PROCESS VIEW**

A process is an activity or a set of activities with clearly defined inputs, outputs, structure (rules and conditions) for action, and resource use. Outputs

link a process to its successor processes, and inputs link it to processes of which it is a successor. Structure of the process defines how it is to be performed and what conditions need to be satisfied. For example, in an engineering heat treatment process it may stipulate that the component is to be heated in an oven up to a certain temperature and then immediately quenched in an oil bath. Resource use defines the resources, such as equipment, tools, skills, and so on, required to complete the process.

The whole enterprise can thus be conceived of as a linked system of processes that can be used by an organization to synchronize its efforts to the customer's needs. In a domain view of the enterprise, the handoffs between functions may not be coordinated. Since performance of a function is often measured by the rate of output or capacity utilization, any difference between production rate at manufacturing and sales rate at marketing may lead to either an inventory buildup or dissatisfied customers. In a process view this is less likely to happen, as the output rate of a process must match the desired input rate at a successor process. An assembly line, if it could respond to changes in customer demand by varying its throughput, would be a good example of a process view. Control systems such as JIT have used a process view to design a synchronization mechanism that links the output and input rates at processes with kanban. A process can be defined as broadly as "order management" or as narrowly as "recording a transaction" or "moving material." A large enterprise can thus be structured as a set of a few broadly defined processes (usually 15 to 20 broad processes for an enterprise [Davenport 1993]) with several narrowly defined subprocesses for every broad process. In Table 1.1, the typical sets of broad processes employed by IBM and Xerox are shown.

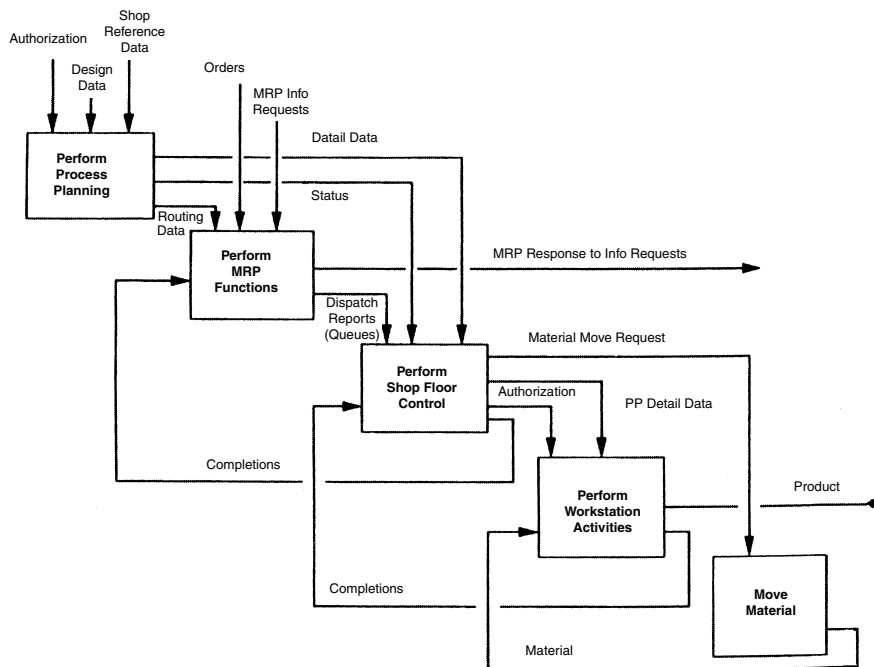
### Process Modeling

To construct a horizontal process view (in contrast to a vertical domain view), the processes must be interrelated in terms of inputs and outputs. A modeling construct called IDEF<sub>0</sub>, developed by the U.S. Air Force, can be used as a graphic tool. An IDEF<sub>0</sub> representation of broadly defined manufacturing processes—perform process planning, perform MRP function, perform shop floor control, perform workstation activities, and move material—is shown in Figure 1.2. IDEF<sub>0</sub> models of the subprocesses corresponding to two of the broad processes (MRP function and shop floor control) are also shown in Figures 1.3 and 1.4.

<i>IBM</i>	<i>XEROX</i>
Market information capture	Customer engagement
Market selection requirement	Inventory management and logistics
Development of hardware	Product maintenance
Development of software	Product design and engineering
Development of services	Technology management
Production	Production and operations management
Customer fulfillment	Market management
Customer relationship	Supplier manager
Customer feedback	Information management
Human resources	Financial management
Marketing	Human resource management
Financial analysis	Legal
Accounting	Capital asset management
IT infrastructure	

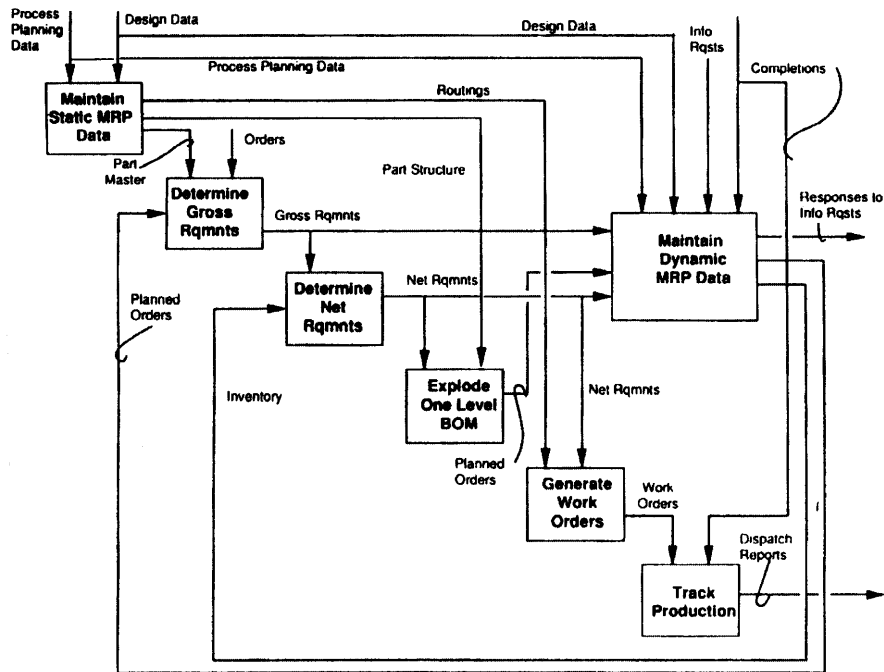
**Table 1.1: Broadly Defined Processes**

(Source: Davenport 1993. Adapted by permission of Harvard Business School Press, © Ernst and Young 1993.)



**FIGURE 1.2: IDEF<sub>0</sub> DIAGRAM OF MANUFACTURING FUNCTION**

(Source: Hsu 1994. Reprinted by permission of John Wiley & Sons.)



**FIGURE 1.3: IDEF<sub>0</sub> DIAGRAM OF MRP**

(Source: Hsu 1994. Reprinted by permission of John Wiley & Sons.)

While IDEF<sub>0</sub> provides a very useful horizontal process view, it lacks the decision-making perspective of coordination, as the metrics of performance and parametric relationships are not defined. Second, as seen in Figures 1.2 to 1.4, it may not be possible to keep the relationship totally horizontal. That is, a certain degree of parallelism cannot be avoided in a single diagram. Various logical-relationship diagrams, such as the data flow diagram (DFD), which links the processes with information flows, have been suggested. Systems algebra and mathematical functional relationships have also been used. Corresponding to IDEF<sub>0</sub>, we may define a mathematical relationship linking the output to other factors as

$$\vec{O} = f(\vec{T}_i, \vec{S}_i, \vec{R}_i) \tag{1}$$

where

$\vec{O} = f(O_{i1}, O_{i2} \dots O_{ik})$  is a vector of outputs from process *i* to all other processes

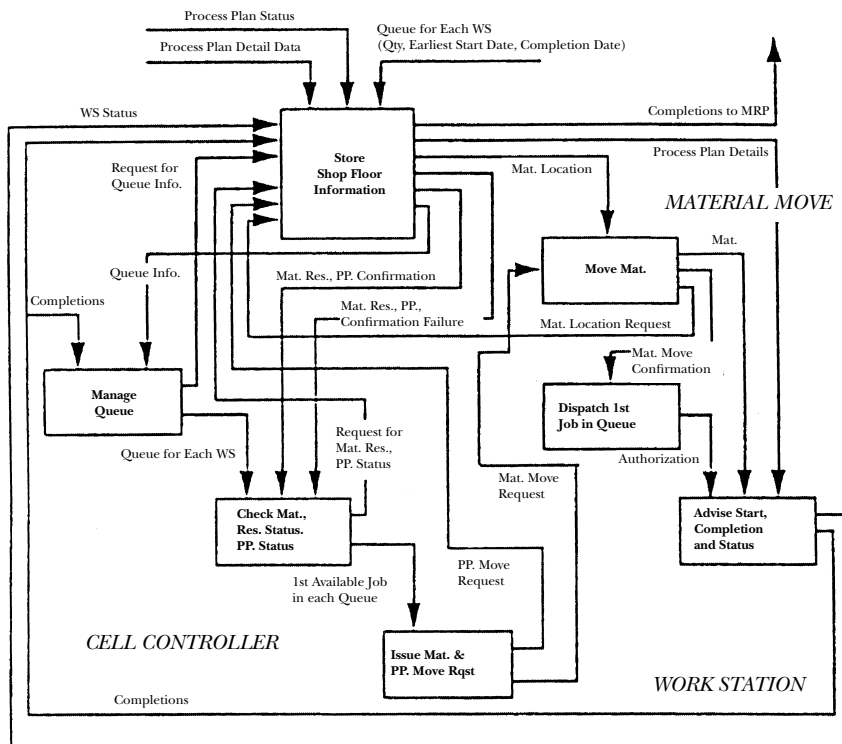


FIGURE 1.4: IDEF<sub>0</sub> DIAGRAM OF SHOP FLOOR CONTROL

(Source: Hsu 1994. Reprinted by permission of John Wiley & Sons.)

$\tilde{I}_i = (I_{i1}, I_{i2} \dots I_{ih})$  is a vector of inputs at process  $i$  from all other processes

$\tilde{S}_i = (S_{i1}, S_{i2} \dots S_{im})$  is a vector of possible structure criteria at process  $i$

$M (m \in M)$  is the set of criteria

$\tilde{R}_i = (R_{i1}, R_{i2} \dots R_{in})$  is a vector of resources available at process  $i$

$N (n \in N)$  is a set of resources.

The above relationship suggests that outputs from a process vary according to the type of resource availability and controls on process decisions, and the nature and quality of inputs at that process. Such relationships can be empirically determined for a few select scenarios, which can then be used to predict the behavior of the function in other scenarios. Chakravarty and Ghose (1993) have shown how a functional relationship

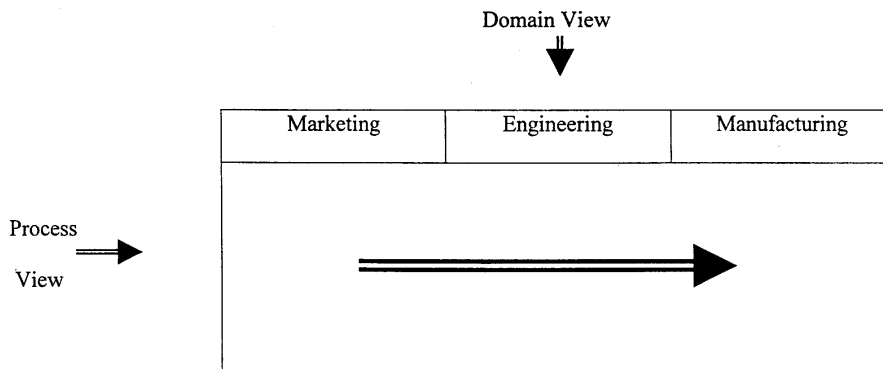
of inputs and outputs can be used to determine a minimum number of required processes (such as advertising and warranty) that would increase quality perception of a product to the highest level. They use a mathematical programming formulation that determines the above (minimum) set of processes in response to queries related to product improvement. In a different study Chakravarty (1997) has used data envelopment analysis (DEA) to link the choice of dispatching rules (outputs) to shop floor status (inputs). An artificial neural net model is another form of functional relationship of inputs and outputs. Balakrishnan, Chakravarty, and Ghose (1997) have successfully modeled the link between customer-desired and engineering-designed attributes to predict design specifications (outputs) of cars, targeted to specific market segments (inputs).

Barua, Lee, and Whiston (1996) argue that some of the variables in a relationship such as in equation 1.1 are complementary instead of being independent. For example, payoff from investment in process reengineering is not significant unless there is a corresponding investment in information technology. Using supermodular functions as defined by Topkis (1994), they establish how complementarity affects payoff, and how complementary variables in the process view of an enterprise should be varied together to maximize payoff. In their model they suggest using variables such as level of intraprocess sharing, level of access to resources, functionality of interprocess interface, functionality of decision aids, level of performance monitoring, transaction simplicity, level of process integration, size of customer base, and unit operating cost. The problem is that most such variables are hard to quantify, and the authors do not provide any information on how to obtain them from empirical data.

### Implications of Process View

A process view, in theory, is an action-oriented plan where the interrelationship between any pair of processes is clearly defined. In Figure 1.5 we provide a contrast between a domain and a process view.

With a domain view of the enterprise, a product development project would lead to the so-called over-the-wall design (Clark and Wheelwright 1993). That is, marketing intelligence on new products is passed on to engineering only periodically (usually in a batch mode), engineering completes the design without manufacturing input and then passes it on



**FIGURE 1.5: DOMAIN AND PROCESS VIEWS**

for prototype tests, and so on. In the process view, on the other hand, a heavyweight cross-functional team would be assembled that would be responsible for pushing the product's development from marketing to manufacturing and beyond. The heavyweight team is empowered to obtain resources from engineering, manufacturing, and other departments as and when required.

Modicon Inc. is a good example of what a process view can do in product development. It reduced the time to market of six products in automation control by more than 70% by using a cross-functional team for product design (Byrne 1993). In the past, manufacturing did not get involved in the design process until the design was brought to the factory, at which stage the cost of any design changes would be exorbitant. Now the team of 15 managers from engineering, marketing, and manufacturing routinely works together on the design process.

Some proponents of process reengineering advocate a total process view with no domains. While such a structure would be very efficient in terms of responding quickly to the market changes, it is by no means certain that it would be effective from a cost perspective or from a strategic perspective. Consider two separate product development projects, A and B. Since the projects would have parallel horizontal views, there would be no resource sharing in engineering or manufacturing between these two products. In an enterprise where hundreds of such projects may be in progress, the cost of resources would soon get out of control. It is not clear how one would provide interproject coordination and overall control of

projects without a higher-level control system (metasystem). But the very existence of such a metasystem would be in conflict with the notion of parallel and horizontal process views. Companies may use a combination of broadly defined processes, as in Table 1.1, and narrowly defined processes or subprocesses to overcome some of the above difficulties. A broadly defined process, since it is a collection of subprocesses that are mostly unique to it, can look a lot like a domain.

From a strategic point of view, the role of innovations in the enterprise is crucial. Davenport (1993) suggests a series of questions, answers to which should form the building blocks of innovation. These are: (1) How could we do things differently? (2) How will it work? (3) How well will it work? (4) What things have to go right? (5) Why might they not go right? Consider again the two projects for products A and B and try to imagine how the design engineer for project A will answer question (1) (how things could be done differently). Unless there is a diffusion of knowledge from other projects to project A, engineer A's search for alternatives would be limited at best. We can easily extend this argument to each of the other four questions to see that A's search for alternatives would not go very far. Therefore, without a functional structure (domain view), the expertise related to a function would be hard to evolve. Since there is no ownership of processes, the innovation potential of the enterprise will be questionable, although the individual processes could do very well in performing assigned tasks. Business consulting firms such as Ernst and Young (Chard 1997) and KPMG (Alavi 1997) have developed special organizational structures to capture consultants' experience (knowledge) from individual consulting assignments so as to make it available to others in the company on demand.

Finally, since processes may change quite often, an organization structure based on process view is not likely to be very stable. Virtual organizations, where at the start of a new project its process view is added to the system and on completion it is deleted from the system, have been proposed. While this may be feasible in certain industries such as consulting, oil exploration, and construction, it would not be cost-effective in a manufacturing company. A structure in which a process view is embedded within each function may be more appropriate for such firms.

## 1.4 DECISIONS AND INFORMATION FLOW

Whether an enterprise is structured as a domain view, a process view, or a hybrid, the means of coordination (or linkages) between domains or between processes need to be structured carefully. Market economists suggest a decentralized structure where the functions (or processes) are coordinated by transfer price (Alles and Datar 1998), incentives (Porteus and Whang 1991), price discounts (Chakravarty and Martin 1991; Dada and Srikant 1987; Banerjee 1986), and negotiations (Nash 1950). Other suggested approaches are information flow (Ives and Learmonth 1984), agency theory (Baiman 1982), ownership rights (Jensen and Meckling 1992), and intelligent agents (Wooldridge and Jennings 1995). Information system planners suggest a more integrated (centralized) structure.

### Coordination Mechanisms

There are a number of coordinating mechanisms a company can choose from, depending on how it is structured. Two important determinants of organization structure are the distribution of decision-making authority and access to relevant information at any decision-making point (Gurbaxani and Whang 1991; Hill and Jones 1995). The two coordinating mechanisms commonly discussed in the literature are centralization and decentralization of decision making. Another mechanism is called transnational in an international context (Bartlett and Ghoshal 1991) and fully distributed in a domestic setting (Anand and Mendelson 1997).

The three coordination mechanisms—centralized, decentralized, and fully distributed—represent different trade-offs between information availability and the quality of decisions. For domains such as manufacturing and marketing, information categories used for decision making are different. In marketing, such information categories describe price, customer preference, market share, market segment, promotions, and distribution. In manufacturing, they describe processing rates of machines, process plans, machine setups, in-process inventory, operations scheduling, and capacity availability. Most of these information types are measurable, and they are transferable between domains. We call this social knowledge, as it is available to all. In any domain there exists another form of knowledge, called tacit knowledge. For example, whereas the processing rate of a machine is measurable (social knowledge), the way to

tweak it so that its output gets closer to specification is not (tacit knowledge). Similarly, while the price charged for a product in a market can be quantified, personal relationships with the customers that help increase sales cannot be. Anand and Mendelson (1997) show how the three different coordination mechanisms can be differentiated by the mix of tacit and social knowledge used for decision making in each, and by how profit expressions are obtained for each coordination mechanism.

While profit (based on unit price, unit cost, and sales) is one measure of system effectiveness, there are many other less tangible factors that are equally important. These include responsiveness to customers, innovations, and coordination of production with customer needs. From our earlier discussion, it is clear that in a decentralized system, innovations and responsiveness to customers are likely to improve. The manufacturing cost, on the other hand, is likely to increase, since manufacturing would not be able to take advantage of component and other forms of commonalities. In centralized coordination, production will be planned according to a demand pattern that would be conveyed to the central decision maker by the marketing domain in the form of social knowledge. However, since the tacit knowledge about relationships with customers and the idiosyncrasies of the customers cannot be conveyed to the central planners, production plans will not be as synchronized with the market as in decentralized coordination. Observe that in fully distributed coordination, decisions would be made in each domain individually (as in decentralized coordination), but the social knowledge from all domains along with the tacit knowledge of the individual domain will be made available for decision making in that domain.

To understand the trade-off between information processing and information flow, consider the following:

number of social knowledge entities in domain  $i = s_i$

number of tacit knowledge entities in domain  $i = t_i$

number of domains =  $n$

(a) Centralized Coordination

$$\text{cost of information transfer} = \lambda \sum_{i=1}^n s_i$$

$$\text{cost of information processing} = \mu \sum_{i=1}^n s_i$$

where  $\lambda$  and  $\mu$  are constants.

(b) Decentralized Coordination

$$\text{cost of information transfer} = 0$$

$$\text{cost of information processing} = \mu \sum_{i=1}^n (s_i + t_i)$$

(c) Fully Distributed Coordination

$$\text{cost of information transfer} = \lambda (n - 1) \sum_{i=1}^n s_i$$

$$\text{cost of information processed} = \mu \left\{ n \sum_{i=1}^n s_i + \sum_{i=1}^n t_i \right\}$$

It is clear that the costs of information transfer and processing in fully distributed coordination will exceed their corresponding values in centralized and decentralized coordination mechanisms, but the quality of the decision made would be far superior, as the decision maker in each domain will have access to *all* social knowledge in the system and that domain's own tacit knowledge.

To compare total benefits with total costs, let  $W$  and  $\Pi$  denote the total cost (information and process) and benefits, respectively, and  $C$ ,  $D$ , and  $F$  denote the three coordination mechanisms, respectively. It is clear from examining the above expressions that for  $n = 2$  (i.e., two domains such as manufacturing and marketing), we can write

$$W_F = W_C + W_D$$

However, for  $n \geq 3$ ,

$$W_F > W_C + W_D$$

That is, information-related cost in fully distributed coordination increases faster than the combined costs of centralized and decentralized coordination when the number of domains to be coordinated increase.

Therefore, for the fully distributed coordination to be desirable,  $\Pi_F$  must also increase much faster than  $\Pi_C$  or  $\Pi_D$  with the number of domains. If that is not the case, distributed coordination should be applied between pairs of domain groups (instead of individual domains), and the domains within each group will have within-group distributed coordination.

### Intelligent Agents for Coordination

An approach for simplifying information retrieval and transfer is the use of intelligent software agents that may reside at the interface of domains. Such agents are being developed rapidly in the context of the Internet (Sycara and Zeng 1996; Wooldridge and Jennings 1993). Such agents would be useful when the number of information entities being transferred across an interface is large and information content is either ambiguous or changing constantly due to innovations within individual domains. The idea of intelligent agents is an extension of the ideas used in agency theory. That is, an agent is assigned a specific set of tasks with well-defined expectations. Unlike real agents, they do not receive any compensation, however. The agents are endowed with decision-making characteristics to optimize their performance. The agents are empowered to retrieve data from databases in one domain, process them, derive inferences, and deliver them in the form specified by the users in another domain, as shown in Figure 1.6. Applets, used in the Java programming language, have some of the above characteristics. We shall see in more detail in Chapters 2 and 10 how such agents can enhance decision quality at the interface between marketing and manufacturing. Mathematicians such as Goertzel (Petzinger 1998) have begun creating software agents that would roam across networks, seeking patterns in numbers, words, and the behavior of other agents. They claim that such networks could eventually recognize context, nuance, concepts, and the rules of grammar. Ex-

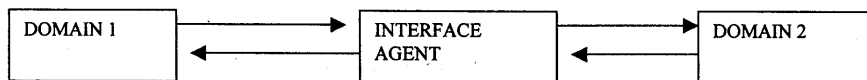


FIGURE 1.6: INTERFACE AGENT

periments are under way by a Wall Street firm to assess how well such a network, designed as a company's intranet, performs the company's market analysis.

## 1.5 DYNAMIC ENTERPRISE

The combination of structure (domain and process views) and coordination mechanism (centralized, decentralized, and fully distributed) generate six possible scenarios, shown in Table 1.2, where the salient characteristics of each scenario are shown. The competitive advantage of an enterprise, as discussed earlier, is born out of innovations, price, variety, quality, and response time. Using the information in Table 1.2, the two views of an enterprise can be positioned as in Table 1.3.

It is clear that for an enterprise to compete in all four dimensions shown in Table 1.3, it should ideally be able to switch back and forth between domain and process views. This is a form of agility that requires that the enterprise be structured to be able to project any of the two views as

	Centralized	Decentralized	Fully Distributed
Domain View	<ul style="list-style-type: none"> <li>Total system social knowledge is used</li> <li>Tacit knowledge is unused</li> </ul>	<ul style="list-style-type: none"> <li>Domain social and tacit knowledge are used individually within each domain</li> </ul>	<ul style="list-style-type: none"> <li>Total system social knowledge is used by all domains</li> <li>Tacit knowledge is used within individual domains</li> </ul>
Process View	<ul style="list-style-type: none"> <li>Rules of each process are determined centrally</li> <li>Information flow from adjacent processes is used for updating input and control operations</li> </ul>	Chaos	<ul style="list-style-type: none"> <li>Intelligent interface agents between pairs of processes</li> <li>Individual processes decide which other processes to interface with</li> </ul>

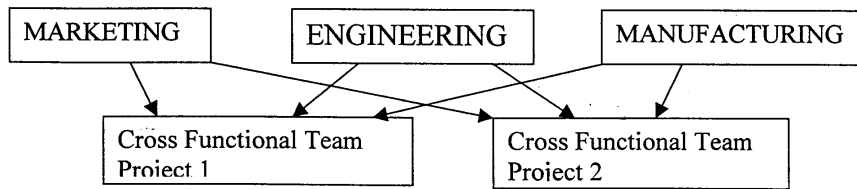
**Table 1.2: Interactions of Domain and Process Views and Coordination Mechanism**

	<b>Domain View</b>	<b>Process View</b>
<b>Innovation</b>	<ul style="list-style-type: none"> <li>• Ideal for using shared knowledge and knowledge diffusion</li> <li>• Pride and ownership of knowledge, not products</li> <li>• Can use tacit knowledge for breakthroughs</li> <li>• Decentralized or fully distributed coordination</li> </ul>	<ul style="list-style-type: none"> <li>• Fragmented knowledge</li> <li>• Too focused</li> <li>• Fully distributed coordination with intelligent agents may be used</li> </ul>
<b>Quick Response</b>	<ul style="list-style-type: none"> <li>• Nonexistent ownership of products</li> <li>• Batch mode of operations is common</li> <li>• “Over-the-wall” syndrome</li> <li>• Centralized coordination would be necessary</li> </ul>	<ul style="list-style-type: none"> <li>• Geared to tracking of products</li> <li>• Tight control on the process inputs and outputs</li> <li>• Can create exception to push through tardy jobs</li> <li>• Centralized coordination</li> </ul>
<b>Variety</b>	<ul style="list-style-type: none"> <li>• Can run multiple product development projects concurrently</li> <li>• Decentralized or fully distributed coordination</li> </ul>	<ul style="list-style-type: none"> <li>• Structured for horizontal parallel views</li> <li>• Not cost-effective for multiple products</li> <li>• Fully distributed coordination required</li> </ul>
<b>Quality</b>	<ul style="list-style-type: none"> <li>• Manufacturing craftsmanship and quality in decentralized coordination</li> <li>• Product quality requires customer input and fully distributed coordination for product development</li> </ul>	<ul style="list-style-type: none"> <li>• Extremely effective for controlling quality of individual processes with SPC</li> <li>• Good for process improvement</li> </ul>

**Table 1.3: Competitive Advantage and Enterprise Views**

and when required—domain view primarily for innovation and variety, and process view primarily for quick response and process quality.

The enterprise may be structured as a domain view, where the domains are interfaced with one another by intelligent software agents. These agents can then be used to create a process view, on demand, by pulling together relevant information from different domains, corresponding to the processes of the product or service in question. This would represent an online implementation of permanent cross-functional teams (Hill and Jones 1995). The cross-functional teams shown in Figure



**FIGURE 1.7: CROSS-FUNCTIONAL TEAMS IN A DOMAIN VIEW**

1.7 are not physical entities separated from the domains of marketing, engineering, and manufacturing. They are created online by software agents that track individual projects and identify the resources associated with a project in each domain.

In such a structure ownership will have to be divided: process ownership to the domains and product ownership to the cross-functional heavy-weight teams. How resources are allocated between innovations and value creation will obviously depend on the competitive posture of the enterprise. Competition based on quick response, time to market, focused production, and focused market segments will require the process view to get priority resource allocation. To compete with innovative products, variety, and total quality, the domain view would get prominence.

To get the best out of the manufacturing-marketing interface, it must be subjected to two types of forces: the drive from marketing for increased variety, quality, and quicker response, and the force of moderation from manufacturing in terms of commonalities, focus, substitutes, and reengineering. For competitive advantage, these two forces should be balanced, and they can be balanced in a productive way only if both manufacturing and marketing domains are proactive. For a domain such as manufacturing to be proactive, several things need to happen. First, it should be continuously innovating new processes, materials, and equipment. Second, it should be able to access databases in other domains such as marketing to be able to anticipate what customers may be looking for and how the marketing domain plans to respond. Third, the intelligent agents that scan the inter-domain and external environments must be fine-tuned and protocols must be perfected. Finally, a mechanism should be in place to quickly assess the impact of alternative proposals on the manufacturing domain.

Observe that if both manufacturing and marketing functions are

proactive, it becomes easier to implement a fully distributed coordination that can find synergy between the drive of the marketing domain and the moderation of the manufacturing domain.

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