TOTAL ENTERPRISE AUTOMATION

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Abstract

Manufacturing Enterprises are networks of companies in alliance sharing the same destiny for mutual business advantage. In such networks, end-to-end material and information flows—from raw material production to retailer sales—are optimally and collaboratively managed to create value to the customers and other stakeholders. In this paper, we first introduce the configuration of the *manufacturing enterprise* and identify the automation and information technologies that are critical for its effective and efficient operation. We then present a methodology that identifies the value delivery processes of a manufacturing enterprise, determines which of these are critical for gaining competitive advantage, benchmarks their performance, and redesigns the organizational, technological, and human resource elements of the enterprise to gain superior operational and financial performance. We then identify five performance measures—leadtime, variation, cost, capacity, and flexibility—and briefly introduce different modeling methods useful in the analysis of manufacturing enterprises.

1 Introduction

The emergence of integrated manufacturing enterprises is a recent phenomenon and is a result of the recent advances in international logistics and information technologies. *A manufacturing enterprise is a group of independent companies, often located in different countries, forming a strategic alliance with the common goal of designing, manufacturing, and delivering right-quality products to customer groups faster than other alliance groups and vertically integrated firms.* Such networks are common in all industrial sectors including the automobile, pharmaceutical, aerospace, electronics, computer, food, and apparel industries. The lowering of trade barriers by various countries, combined with rapid advances in logistics and information technology, has led to the proliferation of global manufacturing networks. In global manufacturing of this kind, components may be sourced from several countries, assembled in yet another country, and distributed to the customers all over the world. These networks are not generally under single ownership but are group formations of independent companies in alliance for a specific and special purpose that compete with similar cooperating networks. The enterprise is to be designed by bringing together companies with complementary competencies, using appropriate automation and information technologies and mathematical optimization techniques with the primary goal of winning a sizable market share.

The formation of manufacturing enterprises can be interpreted as the generalization of the concept of division of labor of Adam Smith [1], who suggested that for production efficiency, work needs to be divided into tasks and tasks into subtasks, and workers need to be assigned subtasks. In manufacturing enterprises, each company in the alliance group specializes in what it does best, and the membership covers all competencies that are critical to the mission of value delivery to the customers. For a manufacturing enterprise to succeed, the critical competencies include product design and development, process design, production, distribution,logistics, product maintenance, information systems and processing, etc. No single company can have world-class competency in all these areas but a well formed network can. Thus, a strategically formed manufacturing enterprise can provide a formidable competitive advantage.

To win customers in the presence of competition, all the value delivery processes of the enterprise such as the customer order-to-delivery, procurement, production,supply chain and new product development processes have to be effective and efficient. Further, coordination of the goals of the constituent companies towards the enterprise goals is important. Thus, for these networks to succeed, there is a need for optimal design and coordination of the value delivery processes mentioned above. This need calls for development of systematic analysis methodologies for evaluating the performance of value-delivery processes. In this paper, we first introduce the configuration of the manufacturing enterprise and identify the automation and information technologies that are critical for their effective and efficient operation. We then present a methodology that identifies the value delivery processes of a manufacturing enterprise, determines which of these are important for gaining competitive advantage, benchmarks their performance, and redesigns the organizational, technological, and human resource elements of the enterprise to gain superior operational and financial performance. We then identify five performance measures—leadtime, variation, cost, capacity, and flexibility—and briefly introduce different modeling methods useful in the analysis of manufacturing enterprises.

2 The Manufacturing Enterprise

In traditional manufacturing, all companies involved in the product delivery, such as suppliers, manufacturers, distributors, retailers, and logistics providers, act as islands of excellence producing goods to forecast or order. There is no coordination between various companies except for some contractual agreements for supply of materials. Even within each company, the three fundamental functions—procurement, production, and delivery—are managed independently, buffered by large inventories. Generally, distribution centers collect customer orders and also forecast the demand. This information is used to project the replenishments needed from the manufacturing plants for several time periods into the future. This in turn will trigger the orders to the component and raw material suppliers. The continuity of material flow is maintained by holding inventories throughout the network in the form of raw materials, components, subassemblies and finished goods. The information flow is generally serial in nature and is paperbased. Several performance and stability problems such as high inventory levels, mark downs, stockouts, and excessive swings in the inventory at various echelons (bullwhip effect) in the supply chain are reported in the literature [2, 3, 4].

Enterprise management differs from traditional contract-based cooperation between companies for procurement, manufacturing, logistics, and product delivery in at least three ways: (1) the enterprise acts as an interdependent system but not as a set of isolated independent companies; (2) all members of the enterprise share the same vision, mission, goals, and destiny; and (3) all members have a vested interest in the ultimate success of the enterprise by meeting the needs and expectations of the customers, and thus decisions are made to benefit the entire enterprise rather than the individual companies. Mutual trust and shared destiny are needed to reap the benefits of integration and coordinated planning. The interorganizational support systems are designed to maximize the sharing of the information, resources, and expertise.

Increasing competitive pressures and market globalization are forcing companies towards greater integration so that higher levels of service can be offered to customers at lower cost. Figure 1 shows the schematic of an integrated manufacturing enterprise . A well-designed logistics network provides a streamlined material flow between all parties, cutting down the lead time and cost of moving the raw materials, subassemblies, and finished goods to their destinations. The extranet, a secure and reliable communications network linking all the companies of the enterprise, provides the information integration. By providing the right information at the right time to all the stakeholders, the extranet enables efficient logistics and effective decision making. This integration will have a profound effect on the inventory levels and also on the cost of delivery.

Our description of the enterprise as depicted in Figure 1, includes both the physical network that provides seamless material flow as well the information network. The ability to move information at electronic speeds breeds the need to move goods at comparable speeds. In other words our diagram considers both front-end (customer to business)and back-end (retailer to the other partners) of the manufacturing enterprise. This would avoid the order fulfillment problems of the type recently reported[3].

2.1 Enterprise Facilities

Here, we are concerned with the location, size, and organization of various facilities, such as manufacturing plants, distribution centers, and procurement and service offices. The conventional reasons to locate of manufacturing facilities in various countries, include taking advantage of cheap labor and infrastructure facilities, government subsidies, tax relief, etc., and also to gain access to local markets (thus meeting government regulations) and technologies. Location of facilities in several countries will certainly increase the

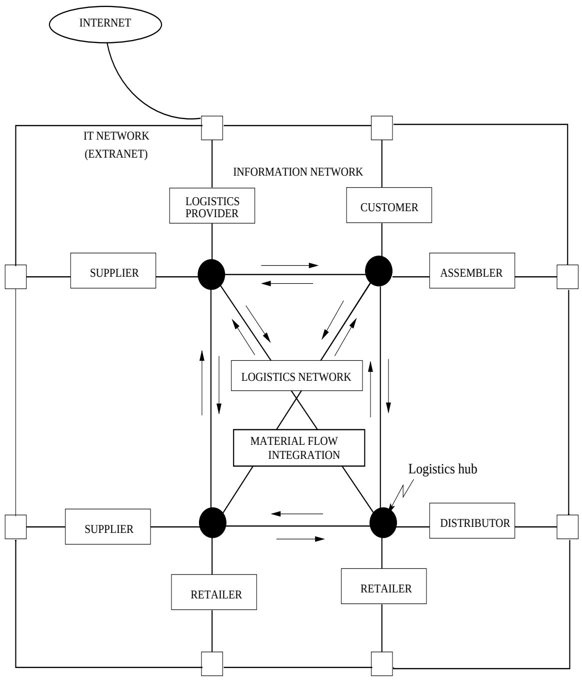

Figure 1: Manufacturing Enterprise

complexity of coordination, scheduling, transportation, and in-transit inventory. Here we talk of three important subsystems of an enterprise.

2.1.1 Staged manufacturing:

The ability of an enterprise to serve several product markets through a single network is an example of economies of scope. Manufacturing plants are the primary contributors to this flexibility. Manufacturing facilities could be organized as several small focused factories dispersed geographically or as one large flexible factory producing several products. Also, manufacturing could be done in a single stage from raw materials to components to subassemblies to assemblies. It could also be done in multiple stages by locating factories for different stages in various countries. This is because, sometimes it is cheaper to ship components and subassemblies over long distances than to ship finished products. Multistage manufacturing is common in PC and semiconductor manufacturing.

Decisions regarding the number of stages of the manufacturing activity and the customization stage at which the product is earmarked for the customer (at the labeling stage, packaging stage, assembly stage, subassembly stage, etc.) can profoundly influence the enterprise architecture. Such decisions can be analyzed by building cost and cycle time models[5, 6, 7].

2.1.2 Distribution:

Distribution often implies inventories of finished or semi-finished products delivered from a factory to the distribution center and then to the customers. Some distribution centers act as final customization points where the final assembly of such things as power supplies and power cards is done, thus efficiently managing the product variety. Third party logistics providers such as Fedex have dozens of distribution centers around the world, where customers store fast moving merchandise at the transportation hubs to serve the customers more quickly and easily and at less cost. In recent years, distribution has been a beneficiary of advances in information and automation technologies and also innovative practices such as cross-docking.

2.1.3 Transportation:

Air, rail, truck, water, and pipeline are different modes of transport with different economic characteristics. Loading and unloading facilities; communication facilities onboard vehicles to receive telephone, fax, Internet, and EDI messages; and alliances between transport, distribution, and production partners are important issues. Delivery within the window of time specified by the customer is rated as the most important service quality. Transit time determines pipeline inventory, and its variability determines the buffer or safety stock necessary. Large transit times also reduce the ability to respond quickly to the market and thus the effectiveness of the manufacturing enterprise.

2.2 Business-to-Business Communications

In a manufacturing enterprise, information is actually the vital commodity for exchange between partners, and it also represents a large percentage of the cost structure. In the health care industry, for example, the patient records, diagnostic test results, physician notes, and insurance claims form 30% of the total health care costs. There is a tremendous amount of information flow between the stakeholders of the enterprise. If one can reduce the information asymmetry between manufacturers and suppliers then substantial cost reductions are possible. This will enable the partners to make decisions based on global information that benefits the entire process.

A variety of information-sharing patterns are practiced in the industry. These vary between the two extremes of sharing no information and sharing all relevant information. These patterns are marketed as best practices in the industry circles and include vendor-managed inventories, quick response manufacturing, supplier scheduling, JIT purchasing, JIT II, and efficient consumer response [8]. Basically, these are information-sharing patterns among two or more partners. An enterprise derives its competitive advantage because of sharing of information with its partners on demand forecasts, point of sale data, production schedules, logistics plans, market trends, etc. Thus, the only uncertainty is the market uncertainty, which could be partially influenced through differential pricing.

Electronic point of sale (EPOS) systems have made possible automation of stocktaking and replenishment i.e. sales-based ordering. Sharing of EPOS information among partners, makes possible scheduling of production and logistics activities in relation to the demand. One of the recent trends is to warehouse and mine the EPOS data to determine *which products are sold to whom and in what markets.* This information can be used for forecasting and analyzing the logistics usage patterns and a host of others.

Electronic Data Interchange (EDI) is a tool to exchange business data between organizations in a machine-processable format. EDI standards have evolved over time. The communication is either through dedicated lines or through a third-party valued network (VAN). Encryption and authentication are also provided by the VANs. Internet-based EDI is becoming very popular since it is relatively cheaper than the VAN-based EDI.

Recent developments in the Internet, intranets, extranets, and the World-Wide-Web have immense possibilities for sharing information reliably and securely among partners. It is now possible to transfer funds securely over the network. The Automotive Network exchange (ANX), the most visible of the new wave of business-to-business virtual private networks (VPNs) running over the Internet, promises to provide the network infrastructure to cut costs by billions of dollars and change the way the automotive supply chain does business. ANX provides a common, standards-based global TCP/IP network service to meet the data communications needs of the automotive industry's applications. Using the ANX, each automotive supplier and OEM will need only a single TCP/IP data transport connection to communicate globally with all trading partners. Similarly, grocery companies are trying to form food exchanges, and textile manufacturers have formed AMTEX, the American textile partnership. Instill corporation is a leading provider of e-business services to the food service industry. Oracle has recently announced an open standards exchange for B2B communications.

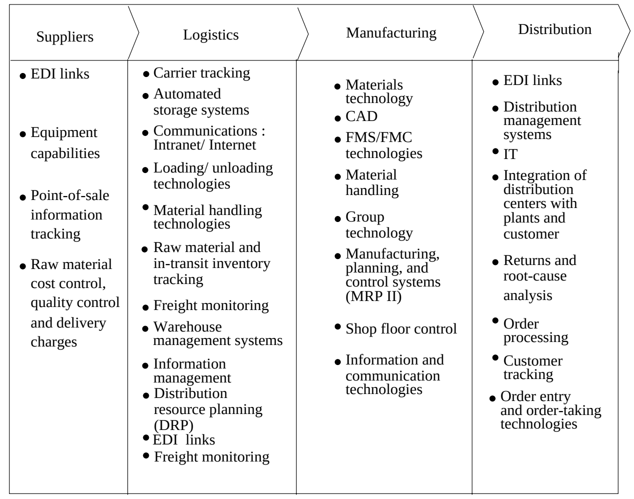

Figure 2: Automation and information technologies in manufacturing enterprises

Whenever information is shared between two parties, the party supplying information is running a risk. When a retailer provides point of sale data to the supplier, then the retailer is running a risk of a shift in bargaining power. In addition, the supplier gains strategically from better forecasts. The retailer has to evaluate the gains of the suppliers and get price advantages through appropriate contracts. Studies are needed to evaluate risk coverage policies in B2B communications.

Figure 2 provides a summary of the information and automation technologies in manufacturing enterprises.

2.3 Interfaces Between The Enterprise Partners

From Figure 1 we can define interfaces between suppliers and manufacturing, suppliers and logistics, manufacturing and distribution, manufacturing and logistics, and finally between distribution and logistics. Basically, there are two extreme relationships between various organizations: one based on the American mass production paradigm and the other based on the Japanese lean production model.

The relationships in the mass production model are adversarial, based on mistrust, threats, and counterthreats between the so-called seller and buyer. Also, contracts are awarded for short time spans creating a transitory perception with the result that renegotiations consume time. The results of such a model include procedural delays, frequent reworking and redesign of products, and inventory buildup.

In the lean production model, collaborative partnership among all elements is encouraged, which will lead to long-term contractual arrangements, information sharing, co-design of products based on trust, and an overall relationship focused on effectiveness and improvement. The relationship is established based on the capabilities, infrastructure, people, and practices of the constituent partners.

3 Analysis of Manufacturing Enterprises

Traditionally, manufacturing enterprises and their constituents have been viewed as a sequential arrangement of functions such as design, manufacture, R & D, marketing, finance, etc. In this paper, we present an integrated approach to manufacturing enterprise analysis and design by first decomposing it into value delivery processes such as customer acquisition, strategy formulation, new product development, order-to-delivery, supply chain process management, etc and then designing the critical business processes for improved performance in measures such as customer service, cost, flexibility and delivery time.

A process is a structured, measured set of activities ordered in time and space, designed to produce a customer-desired output[9]. A process perspective is a horizontal view of the manufacturing enterprise that cuts across the organizations, with product inputs at the beginning and customers at the end. Process orientation either eliminates handoffs or coordinates them effectively. Processes are typically cross-functional. Some processes, such as the supply chain process, are cross-organizational. Enterprises are composed of several interrelated processes that should be efficient and effective in order to gain competitive advantage. Competition will be in terms of processes rather than functions. This means that it is not enough to be a world-class manufacturer of a dishwasher or a washing machine; the company must ensure that its product reaches the customer in time and that he or she loves the product in all respects: looks, features, performance, durability, usability, economy of resources, and a variety of other values.

3.1 Competitive Strategy and Business Processes

A manufacturing enterprise is a bundle of value-delivering business processes, and it will be as effective and efficient as its processes. While all processes are important for the business to succeed, some are more critical than others. It is very important to identify these critical processes so that their performance can be improved. If wrong processes such as inventory control are improved when the need is to supply fresh and new products, then the business will sink.

Enterprise goals reflect the expectations of the customers for the product quality, cost, and delivery reliability. They are derived from what constitutes the competitive advantage and also the critical success factors for the business segment in which the enterprise operates. Goals are the endpoints the enterprise hopes to reach. The competitive strategy of an enterprise is the set of objectives, plans and policies that will enable the enterprise to compete successfully in the markets. The competitive strategy specifies what the organization's competitive advantage is and how it can be achieved and sustained. *Critical success factors*(CSFs) are the things that must go right for any business to flourish. They are the factors that support the attainment of company goals and when properly managed will have a high impact on the company's competitiveness. A CSF can be a characteristic such as price, quality, or delivery time or an industry structural characteristic such as vertical integration. In short, CSFs are factors that give the customers the value that they are looking for. For example, in the semiconductor industry, R & D, manufacturing, and development of generations of new products are major factors that enable a company to succeed. In the automobile industry, styling, cost, dealer network, safety features, etc. may be CSFs.

3.1.1 Critical business processes:

First, it is important to identify the set of critical processes that support the CSFs and form the basis for attaining competitive advantage. If rapid introduction of generations of new products is perceived as the key to gaining competitive advantage by the company and is declared as the enterprise goal, then the new product development process is the core process. If, on the other hand, faster delivery to the customers provides competitive advantage, then the order-to-delivery process, logistics and supplier management are the critical processes. If the cost of producing a product is central to the enterprise goals and provides competitive

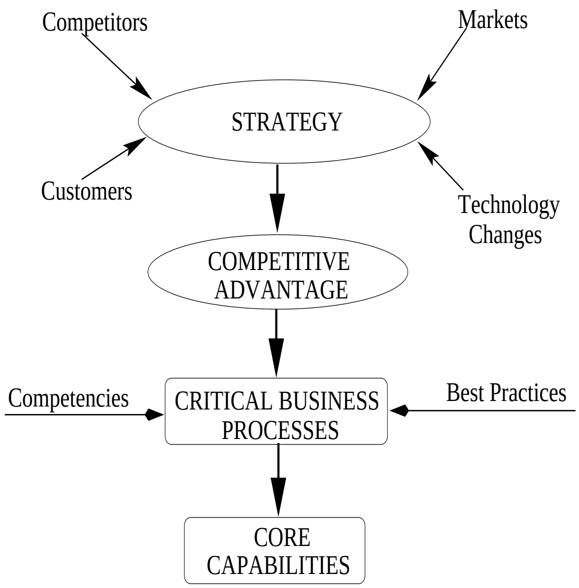

Figure 3: Strategy, critical business processes, and core capabilities

advantage, then design, manufacturing, purchasing, and materials management (i.e., the supply chain process) are critical processes. If the ability to respond to rapidly changing markets is a competitive advantage, then market research and planning and risk management are core processes.

From the above discussion, it is clear that the primary decision to be made concerns what provides the competitive advantage—cost, quality, delivery time, new products, flexibility, etc.—and also to identify the CSFs. The competitive advantage dimension determines the critical business processes that need to be converted as core capabilities with well identified attributes and measurable objectives.

4 Performance Measures

Performance measures are useful to monitor, evaluate, and improve the value delivery processes. They can also be used to compare similar processes in different companies for benchmarking purposes. In traditional manufacturing performance measures are generally defined for an organization and are typically financial in nature. For example, original equipment manufacturers (OEMs) define their own market share, return on sales, or investment. Suppliers and distributors, similarly, define their own metrics. However, this approach is fraught with many ills. First of all, financial indicators are lagging metrics that are a result of past decisions and are too old to be useful in operational performance improvement. More importantly, when several organizations are involved in product manufacture and delivery to the customers, individual financial statements do not give a complete picture of the performance of the product or the delivery process. Also it is important that all the companies involved in the enterprise share the same goals, such as cycle time reduction, six-sigma on-time delivery, or quality or customer-perceived service levels, etc., and exchange information and expertise for the benefit of the entire chain. To illustrate this point, consider a company in a supply chain, say an intermediate component manufacturer, that follows lean manufacturing principles of low cycle time and on-time delivery, but the upstream raw material vendor is not quality conscious and is unreliable in deliveries, and the downstream original equipment manufacturer follows chaotic ordering policies and maintains large work-in-process inventories. Then the lean middle man will have to maintain a huge output inventory to cope with the unpredictable ordering patterns of the OEM and also to counter the unreliable deliveries and low quality of the supplier.

Here, we identify the nonfinancial measures that would indicate the health of the entire value delivery process and hence the health of all organizations involved in it. More specifically, we define seven performance measures—lead time, variation, cost, capacity, and flexibility—and indicate methods for their determination and improvement. This is because a manufacturing enterprise is cross-functional and cross-organizational, has a well-defined starting and endpoints, and the customer is generally the recipient of the final delivery. Measuring the quality along an order-to-delivery process will directly measure customer satisfaction levels. It will also present information on defects in products, missed deliveries, wrong deliveries, incomplete deliveries, delayed installation, etc. Monitoring these measures will help correct the defects and conduct continuous improvement. Similarly, cycle time monitoring in the supply chain networks will help reduce the inventories, establish good supplier relationships, reduce setup times, etc.

In this paper, we consider the following five performance measures for a generic value-delivery process

1. **Lead time:** The lead time of a value delivery process is the interval between the start and end of the process. It is the concept-to-market time in the case of the product development ; the clock time between placing an order to the delivery at the customer site in the case of the procure-

ment process; and the time elapsed from raw material ordering until the final assembly reaching the retailer in the case of the supply chain networks. Lead time reduction by removing non-value-adding activities; using information technologies such as EDI, databases, etc.; and effectively managing interfaces with suppliers, manufacturing, logistics, and distributors is an important exercise.

2. **Variation:** Quality is management of all the work processes so that they are on design target with low variation. This goal is achieved through monitoring the performance for defects, conducting root-cause analysis of defects, and eliminating the sources of defects.

3. **Cost:** Like the lead time, cost also provides tremendous insights into process problems and inefficiencies. Interface costs, margins, and costs in negotiations and inspection are a waste and provide avenues for cost cutting.

4. **Capacity:** The maximum output rate of the enterprise is called the capacity. All the organizations and their functions must be balanced in capacity, otherwise, there will be bottlenecks and delays. Strategic alliances are common among various facility owners in order to have variable capacity. A little overcapacity to meet rush demands can improve the operational measures.

5. **Flexibility:** Flexibility is the ability to meet customer requirements under various environmental uncertainties in various dimensions such as delivery time, schedules, design and demand changes, etc. Flexibility of the enterprise is closely related to product structure and to the technology. Modular designs and automation technologies enhance the ability of the company to meet the customer preferences.

The above five measures are very generic and from them the customer satisfaction levels and the operational effectiveness and efficiency of the value delivery process can be computed.

It is often argued that if the fundamental performance measures are managed well, then outstanding financial performance will follow automatically. However, several companies that went out of business after winning quality awards bear witness to the fact that nontraditional performance measures are necessary but not sufficient for sustainable excellence. Thus it is also important to measure the financial performance of the company in terms of the return on investment and market share. In times of constant change, as we have witnessed in recent years, nothing should be assumed to be fixed: products, customers, markets, businesses, and technology all change.Business managers have to suitably change strategies, nurture appropriate value delivery processes, and define and adapt suitable performance measures and measurement systems to stay in business.

5 Mathematical Models

For the enterprise to be competitive, its critical value delivery processes have to be effective, efficient, and optimal in cost, lead time, and quality. Mathematical modeling provides a systematic foundation for decision making at strategic, tactical and operational levels.

The models useful at the strategic level—for example, for supply chain facility location—are nonlinear integer programming models [10]. Similarly, capacity planning models are also nonlinear integer programming models and are solvable using Lagrangian relaxation [11]. Several other optimization problems can be posed and solved. Operational-level decision making and optimization are conducted using discrete event models.

Manufacturing enterprises are discrete-event dynamical systems (DEDS) in which the evolution of the system depends on the complex interaction of the timing of various discrete events such as the arrival of components at the supplier, the departure of the truck from the supplier, the start of an assembly at the manufacturer, the arrival of the finished goods at the customer, payment approval by the seller, etc. The state of the system changes only at discrete events in time. Over the last two decades, there has been a tremendous amount of research interest in this area. There are several classes of models that are useful in this context. These models can be used for either qualitative or quantitative analysis. Qualitative analysis yields results on stability [12], deadlock analysis[13], etc. There are several methods available for this kind of analysis using Petri nets, queuing networks, etc. While these are fairly well developed in the manufacturing context, in the enterprise context the research is nascent. Quantitative methods, on the other hand, highlight the determination of system performance measures such as throughput and lead time. Markov chains are fundamental models for DEDS. Petri nets and queuing networks are higher-level models. Discrete event simulation is a very general method and is widely followed.

5.1 Simulation Models

Very attractive higher-level general-purpose simulation packages are now available that can faithfully model the value delivery processes of a manufacturing enterprise. These include SIMPROCESS, PROMODEL, and TAYLOR II, to name a few. In a typical value delivery process simulation, synthetic random inputs are used, and the simulation generates corresponding outputs. Several output samples are collected for statistical analysis. Most of the commercial packages have statistical output analysis routines.

The simulation of a value delivery process involves developing a simulation model, coding it, validating it, designing the experiments, and finally conducting a statistical analysis to obtain the performance measures. The simulation model for a enterprise, for example, should contain the submodels of all organizations and their functions, including all the interfaces between the work processes, functions and organizations. Most simulation models ignore the interfaces, primarily because of the vagueness involved in their modeling management.It is very important to develop a model for the interfaces. Another issue that is not frequently addressed is the effect of the organization structure on the performance of a value delivery process.

5.2 Analytical Models

The four modeling techniques useful for analyzing business processes are series-parallel graphs, Markov chains, queuing networks, and Petri nets, or a combination of them.

Series parallel graphs: Series parallel graphs can model any value delivery process by assigning probability distributions to the lead time of the activities in the graphs. These are graphs, showing the precedence and concurrency of the activities of the material and information flow. Their nodes represent the activities and the edges the precedence relationships [14]. Assuming that all the activities are statistically independent, one can determine the mean and variance of the lead times, throughputs, etc.

Markov chains: The use of Markov models in the study of performance of manufacturing systems [13] is well known. Smith and Eppinger [15] have studied design iteration in NPDPs using Markov models. Direct modeling of any value delivery process as a Markov chain would be very difficult and expensive.

Petri nets: It is easy to write down a Petri net model for the value delivery processes. These are similar to modeling work flow management systems. Vander Aalst [16] presents higher-level Petri net models for logistic system modeling. Faithful modeling of iteration synchronization, forks, and joins that arise in value delivery processes is possible using Petri nets. Numerical solution, however, may turn out to be a nightmare. Aggregation of Petri nets and hierarchical modeling may provide a tractable way of handling largeness here.

Queuing networks: The most general situation in a value delivery process can be modeled as a fork-join queuing network model with iteration or reentrancy. An analytical solution of these general models is not available, and approximations are available in only special cases. Some solutions can be found in [11]. This is an area of active research. Several preliminary results on quantitative evaluation of reengineering methods are available in [17].

6 Decision Making in Manufacturing Enterprises

Decision making in the global manufacturing networks is very complex because a large number of organizations are involved and several alternative routes are possible to fulfill an order. An enterprise has several facilities in different geographic locations, producing different products and serving different customers by supplying them with the required variety and lot sizes at the time and place they specify. Thus modern-day manufacturing networks need to solve a five-dimensional decision problem: *When, Where, What and How Much to produce, and for Whom.* This problem is in contrast to the one dimensional decision problem of mass production systems: how to keep the production of a single product for a single market going. The decision making problem is further complicated because all the stakeholders are autonomous and may not share the information, whereas most mass production enterprises are vertically integrated and information is centralized. In section 2.2, we presented several possible information-sharing patterns among the enterprise partners.

Here, we are concerned with identifying the strategic, tactical, and operational decisions in manufacturing networks. The strategic decisions are long-term and are often one-time decisions. They determine the competitiveness of the manufacturing enterprise. These include partner selection, strategic alliances, location of facilities, technology choices and outsourcing decisions. Which products to produce and for what markets are also strategic issues. At the tactical level, the time horizon is weeks or months. Demand forecasting, resource allocation, routing of the orders along the supply chain, subcontracting, scheduling production onto the facilities, load leveling, and bottleneck scheduling are all issues at this level. The operational-level decisions include order processing, production matters, fleet scheduling, inspection, and delivery, to mention a few. These are basically day-to-day decisions. The questions that are addressed at this level include which customer order is to be filled, how to react to breakdown of a truck carrying items to a customer, the disruption of the supply of subassemblies from a supplier due to labor problems, etc. Effective enterprise management involves addressing issues at all the three levels simultaneously.

6.1 Sources of uncertainty:

Basically, all decisions made in the enterprise world have to counter some kind of uncertainty. It is known that retail product stock-outs in the industry occur at an average rate of 8%. The traditional answer to customer service problems has been to increase inventories. Unfortunately, inventory bears a high cost in terms of capital consumption and expense: it is known that inventory costs form one third of total sales. To understand the opportunities for dramatically reducing inventories, it is worthwhile to examine the drivers of inventory.

The inventory is more significantly impacted by the uncertain demand. The more unpredictable the demand is, the more inventory is required to manage the risk. Another potential source of problems for inventory management is the uncertainty of supply processes. Supplier variability drives inventory at both the beginning and the end of value chain nodes. There can be several reasons for its occurrence at each node of the supply chain. One of the most common reasons at the input stage of a value chain node is suppliers failing to deliver what is ordered. At the output node of the chain, inventory depends on production cycle time. It is fairly common for output inventories to be equal to the node process cycle times multiplied by the supply chain throughput. Coordinated planning of supply processes reduces multiple sources of supply variability and the inventory it drives.

Planning and forecasting have made steady and significant improvements over the last several years. Data content and quality have improved, and the understanding of their importance and value has also increased. The use of collaborative planning, forecasting and replenishment can minimize inventories, and enterprise participants can focus on value-added process activities. By focusing on the flow of supply to consumers, without the clouding effect of inventory, participants can discover previously hidden bottlenecks in the flow and address them. In turn, taking care of these now-visible inefficiencies can reduce process costs. Collaborative relationships across the manufacturing enterprise can be more efficient, more cost-effective, and more successful in satisfying consumers than adversarial practices.

7 Conclusions

Global manufacturing network management is very hot research topic. Many researchers around the world are involved in advancing its frontiers . There are lots of white papers, concept papers, and vision papers written by management consultants, ERP vendors, IT companies such as HP, IBM, i2, and Netscape, scheduling software vendors, and market researchers on value chains, Integrated supply chains, Industry clusters, Constellations, Industry webs and so on. The manufacturing enterprise is the critical back-end of the Internet order fulfillment process, and got lot of attention with the booming of I-commerce. Internet based companies such as amazon.com and e-toys are highly successful business ventures with new business models and value propositions. Overall there is lots of excitement all round.

This paper provides an integrated view of manufacturing enterprises incorporating the material flow and information flow integration (See Figure 1). We have also indicated at various points in the text the contribution to this subject from various authors. There is no doubt that manufacturing enterprises and their management will occupy the minds of researchers for few more years. I will point our some directions that need attention.

1. As of now enterprise methodology is offered as a universal methodology—independent of the markets, products and the network architecture. Individual industry segments and regional chains may offer sharper solutions.

2. Most studies concentrate on PCs, deskjet printers, apparels, and automobiles. Grocery chains also got some attention. Recently, there are initiatives on aircraft supply chains. The old industries such as iron, steel, paper, chemical, electrical, petrochemical, and pharmaceutical indus-

tries need attention. There will be large payoffs in these enterprises.

3. Among infrastructure and service networks, the IT supply chains, health care, and banking dominate. Construction supply chains are well developed particularly in UK.

4. Most of the developments in the area of enterprise integration are taking place in the U.S. and to some extent in Europe. In all other countries particularly in Asia, the IT and logistics infrastructure are totally absent. It is important to have integrated enterprises in place, for the success of rapidly expanding e-business ventures around the world.

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