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Information Technology Implementation
Strategies for Manufacturing Organizations:
A Strategic Alignment Approach

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Abstract

It has been an increasingly evident phenomenon that information technology often provides manufacturing-based competitive advantage. This paper develops an evolutionary process for implementing information technology in the manufacturing sector. The evolutionary process contains stages for which transformation to world class manufacturer is prescribed. The process draws upon a strategic alignment model of manufacturing management and information technology. The model is defined in terms of four domains of strategic choice: the structure and infrastructure of manufacturing strategy and the structure and infrastructure of information technology--each with its constituent dimensions. The model is conceptualized in terms of two fundamental characteristics of strategic management: strategic fit (i.e., the interrelationships between structural and infrastructural domains) and functional integration (i.e., integration between manufacturing and information technology functional domains). The way that information technology is implemented is through cross domain alignment via strategic fit and functional integration.

1. Background

A major bicycle manufacturer establishes an automated warehouse for incoming components. Roberts glide up and down the high-rise bays, selecting bins of components under computer control; the bins are passed to a conveyor system; they move around on a path determined by bar code scanners that identify each bin and route it to a stock picker. The stock picker removes items for dispatch to the factory floor as instructed by a computer workstation. An automated guided vehicle rolls off to the factory along a track painted on the floor.

Establishing such a system would cost many millions of dollars. However, due to the quality insurance program for incoming components is in trouble, and bottlenecks in the succeeding operations, the expected efficiency of this system has not been observed. A manually operated inventory system might do as well or even better.

Another case is a supplier in the bicycle industry, which manufactures aluminum mixed body-frame for the bicycle. Because of high price charged in the market, the bicycle style changes often as the fashion goes. Hence its production is limited to small batches. The main task in manufacturing is welding and the company purchased two robots to do the work. But the effort is overwhelmed by technological problems. These two robots are now idle.

Perhaps the managers of this company thought that information technology was a competitive weapon; perhaps they thought that advanced manufacturing technologies incorporating microelectronics were the key to manufacturing cost reduction. However, as long as they don't consider organization design alternative and business process reengineering while information technology is being implemented, information technology would have continued to be a competitive burden.

There is considerable pressure on most organizations to make their operational, tactical and strategic processes more efficient and effective. As the two cases mentioned above, an increasingly attractive means of improving these processes lies in today's wide variety of information technologies. Here the term information technology (IT) is viewed in a broad sense as it refers to any artifact whose underlying technological base is comprised of computer or communications hardware and software. In many organizational environments, such as manufacturing firms, over half of a firm's capital expenditures involves IT. In fact, Jonscher (1983)
suggests that the appropriate use of I/T may be the principal source of future growth for the U.S. economy. However, significant difficulties often plague I/T implementation (Tait and Vessey 1988, Kwon and Zmud 1987, McFarlan 1981).

2. Strategic Management of I/T

There are three major roles for I/T: 'administration'; 'operations'; and 'competitive' (King 1978; Rockart and Scott Morton 1984). The administration role signifies the scope of I/T as the automation of accounting and control functions, which is reasonably well-understood in the traditional literature on management information systems. This role requires the deployment of an efficient I/T platform (including hardware, software, and communication systems) for administration and control and is independent of the strategic management of the organization. The operations role is an extension of the first role and is distinguished by the creation and deployment of a technology platform that creates the capability to automate the entire set of business processes as opposed to only the administrative activities.

In contrast, the competitive role represents a significant point of departure. Extending beyond internal, efficiency focus, the capability now exists for organizations to deploy new I/T applications that leverage the information and technological attributes to obtain different sources of competitive advantages in the marketplace. Increased attention is being paid to the potential role of I/T to shape the basis of competition (Rotenberg and Saloner 1990). However, the emphasis on the competitive role does not exclude the importance of the first two roles. Simon (1992) pointed out that design of information systems must consider in depth business processes of the organization. Hayes and Wheelwright (1981) also indicated that one of the key success factors of Japanese industries is no separation between strategies and operations. But a limited consideration of the first two roles for I/T in modern corporation is sub-optimal with potentially dysfunctional consequences.

There is reasonable consensus on the three-level categorization of the strategy concept - corporate, business, and functional (Hofer and Schendel 1978). Strategy at the corporate level involves the selection of product markets or industries and the linkage among these different businesses to form the corporate profile. Strategy at the business level relates to the requirement of matching environmental opportunities and competitive threats with the efficient deployment of organizational resources. Manufacturing strategy and I/T strategy form parts of cluster of functional area strategies such as marketing strategy, financial strategy, etc., which complement higher level business and corporate strategies.

Implementation of I/T is critically dependent on the business or the sector upon which I/T is applied. The work on I/T implementation suggests that sector differences are significant (Earl 1989). For example, in some sectors like financial services, airlines and retailing, I/T has become the means of delivering the goods and services in the sector. In the manufacturing sector, business and functional strategies are increasingly dependent upon I/T for their implementation. For a service-oriented business, I/T strategy may be the synonym of its product-market strategy. In the case of manufacturing organization, manufacturing planning and analysis begin to highlight the need for technology. Planning for I/T therefore is a derivative of business planning.

I/T implementation with focus upon manufacturing firms will involve interfunctional strategy interactions, namely manufacturing strategy and I/T strategy. There is a glaring lack of systematic frameworks to conceptualize the logic, scope, and patterns of such interactions. An exception is Henderson and Venkatraman's (1990) treatment of the business-I/T connection.

This paper aims to address the need by offering a model to link manufacturing strategy and I/T strategy and to point to alternative strategies for achieving the results that information technology promises.

3. Manufacturing Strategy

As learned from world-class manufacturers, the key point of their achievement is that managers successfully build up manufacturing capability. This depends very much on combining organizational skills and technological ability to produce products better than one's competitors. In addition, their adversary finds it extraordinarily difficult to duplicate capability behind products. Hence a sustainable competitive advantage can be achieved and maintained. To continually enhance that competitive advantage requires the employment of manufacturing strategy (Hayes,Wheelwright and Clark 1988).

Manufacturing strategy consists of a pattern of decisions relating to a manufacturing organization's structure and infrastructure. Decisions of a structural nature are like the hardware in a computer, which include the following: (a) product scope; (b) process technology; (c) manufacturing alliance; and (d) production competence.

Product scope refers to the types and range of products that a manufacturing organization provides, and can be presented as a composite of several underlying variables (Kotha and Orne 1989) such as the following:

1. End product complexity. Both BOM (bills of material) structure and the technical difficulty in manufacturing are addressed in this section. For example, a super computer is much more complex than a personal computer. The structuring of BOM and technical competence required in the former will overwhelm the latter.

2. Variety of end products. As the number of different end products increases, the range of
product line increases. For example, The CoCa-Cola company has increased the number of flavor for its product-Coke.

3. Individual product volumes. The economy of scale used to be the major factor in deciding the profit margins of manufacturing firms. It involves with the time and the frequency of production changeovers. Small production volume often implies low profit margin; therefore, expansion of product scope is limited. However, with the advent of flexible manufacturing, the impact of changeover cost can be reduced.

Process technology consists of the methods and equipment used to manufacture a product or deliver a service. The classification of production process has been found in the literature as a variety of seemingly relevant typologies and taxonomies. A later example is represented in the work of Evans, Anderson, Sweeney, and Williams (1990) which used five process categories: continuous flow, mass (assembly line), batch, job shop, and project. Furthermore, Hayes and Wheelwright (1979) believed that product scope and process type will determine many of characteristics of the productive units.

Unfortunately, the state of the art manufacturing technology has alternated this traditional classification scheme. For example, traditionally discrete parts manufacturing was generally done in batch or assembly line environment. However, with the introduction of flexible manufacturing system (FMS) concepts, these structures can now share some of the same characteristics of continuous flow environments and some of the job shop environments.

The dimension of process technology presented in this paper is building on ideas by Chiantella (1982). This dimension is a composite of three underlying variables: (1) mechanization level; (2) systematization level; and (3) interconnection level.

The level of mechanization is classified as manual, machine, fixed program, and programmable control. The level of systematization is presented in the following order: data collection, event reporting, tracking, monitoring, guide, and control. Chiantella (1982) determines the level of automation for a particular process technology as a composite function of: (a) the level of mechanization; (b) the level of systematization.

The level of interconnection describes the integration level between the various process operations and is a composite of several subordinate factors as follows: discontinuities, technological interdependence, and operational flexibility.

Although specific process stages may differ in their levels of mechanization, systematization, and interconnection, the focus here is on the dominant characteristic of a whole manufacturing system. This often represents a composite of the primary characteristics of the dominant process stages.

Manufacturing alliance relates to what sort of materials, systems, and services are provided through internal operations, what else is to be ordered from vendors, and what kind of relationship is to be established with vendors and business partners. It is essentially the choice of a structural mechanism to organize manufacturing operations.

Production competence refers to a manufacturer's strength in some areas that is based upon his process technology, product scope, and manufacturing alliance. Such strength is often described as a composite function of cost, quality, time, dependability, and flexibility. Production competence may not mean better product design or marketing innovation, but addresses on the ability to make relatively standard products more efficiently, more reliably, and with higher precision.

By infrastructure, on the other hand, it is referred to the management policies and systems that determine how the hardware (structure) is managed. A parsimonious set of dimensions specify infrastructure as follows: manufacturing administration, processes, and skills.

Manufacturing administration includes manufacturing organization's structure, roles, and reporting relationship, which contains the following:

1. Human resource policies and practices, including management selection and training policies;
2. Quality assurance and control systems;
3. Production planning and inventory control systems;
4. New product development process;
5. Performance measurement and reward systems, including capital allocation systems; and
6. Organization structure and design.

Processes refers to the articulation of workflows and the associated information flows for carrying out the manufacturing activities. Manufacturing activities add value to the product by transforming materials, components, or subassemblies into a higher level of components, or assembly. Material flows refer to the movement of materials from one department (location) to another. Because of the number of conversion steps precipitated by the manufacturing process, the material volumes, and the distances involved in most factories, such movements are both numerous and extremely important. Information flows serve not only to coordinate conversion steps and material flows but also to provide the feedback necessary to make improvements in the factory's procedures, process technology, and operating characteristics. Skills refer to the capabilities of the individuals and the organization to execute the key tasks that support a manufacturing strategy.

Coordination between manufacturing administration, processes, and skills will facilitate an organization's operations and eliminate bottlenecks. The design of system involved in manufacturing administration is to influence on the organization's material flows and information flows. The way in which they are handled becomes tasks of the individuals and tasks of the organization. Due to differences between various departments and results from executing tasks, a task
often grows in uncertainty and complexity, in which uncertainty is also an important contributor to factory’s complexity. Uncertainty comes in many forms: uncertainty regarding costs, the quantity and quality if output from a given department or supplier, the lead times associated materials transfer among departments, the production setup or changeover times, and production run times. Reducing uncertainty and complexity firsthand is essential to understand administrative decision rules, flow patterns, and task designs.

4. Information Technology Strategy

The concept of I/T strategy is relatively new and hence open to differing definition and assumptions. Analogous to manufacturing strategy, I/T strategy is conceptualized in terms of structure and infrastructure. Decisions of a structural nature contain three dimensions:

1. System competencies. The focus is on those distinctive attributes of I/T competencies, which are often emphasized by an organization in designing and operating its I/T and add value to its product and services. Principle components are costs of information processing, flexibility to provide different classes of information, and the ability to provide specialized information.

2. Technology scope. It refers to the types and range of I/T systems and capabilities potentially available to the organizations. Examples are electronic imaging systems, local- and wide- area networks, expert systems, robots, etc. Because of the significant investment involved in and the advantages/disadvantages associated with each technology, the choice of the dominant information technology used needs to be based upon the strategy of the organization.

3. I/T alliance. The choices of structural mechanisms available to organizations to obtain the required I/T capabilities. Examples are joint ventures, long-term contracts, equity partnerships, joint R&D, etc. It involves issues such as the deployment of proprietary versus common networks (e.g., the development of independent/third value-added networks versus the development of propriety value-added networks in Electronic Data Interchange) as well as strategic choices pertaining to development of partnerships to exploit I/T capabilities and services (e.g., outsourcing an organization’s data center operations to another organization).

Analogous to the infrastructure of manufacturing strategy, the infrastructure of I/T strategy includes the following:

1. I/T architecture- is comprised of the following four items:
   a. Computing- the information processing hardware and its associated operating system software.
   b. Communication- the telecommunications networks and their associated mechanisms for interlinking and interworking.
   c. Data- the data assets of the organization and the requirements of use, access, control and storage.
   d. Applications- the main application systems of the organization, their functions and relationships, as well as the development methods.

2. Processes- concerned with the work processes central to the operations of I/T strategic infrastructure, including processes for systems development, maintenance, as well as monitoring and control systems.

3. Skills- associated with the knowledge and capabilities required to effectively manage the I/T strategic infrastructure within the organization.

5. The Strategic Alignment Model

5.1 Bivariate Fit and Cross-Domain Alignment

The proposed model is depicted in Figure 1. It covers both manufacturing strategy and I/T strategy, each is composed of structure and infrastructure. There are four key domains of strategic choice. The type of strategic alignment can be categorized as bivariate fit and cross-domain alignment.

Bivariate fit is the simplest type of relationship, linking two domains either horizontally or vertically. Four different types of linkage are delineated as follows:

1. Bivariate fit between manufacturing strategic structure and I/T strategic structure;
2. Bivariate fit between manufacturing strategic structure and infrastructure;
3. Bivariate fit between I/T strategic structure and infrastructure;
4. Bivariate fit between manufacturing strategic infrastructure and I/T infrastructure.

A major benefit of the bivariate fit perspective lies in its simplification of the relevant domain, invoking ceteris paribus conditions. However, many instances of strategic alignment require adaption across a complex set of multiple domains, thus limiting the value of bivariate fit.

Cross-domain alignment is a type of multi-domain relationship, which involves three domains linked sequentially. The strategic role of the one remained could be determined as a result of cross-domain alignment. That is, it can be linked via bivariate fit, either by the structure-infrastructure fit or by functional integration.

5.2 Manufacturing Information System’s Strategic Role

Considering manufacturing strategy alone, Hayes and Wheelwright (1984) indicated that manufacturing can play at least four major roles in a firm’s
competitive strategy. These four roles, or stages of development, fall along a continuum and, given the inertia of most organizations, large or small, any enhancement of manufacturing’s contribution tends to take place through systematic movements from stage to an adjacent one. These four stages of development in manufacturing’s strategic role are stated as follows:

1. Minimize manufacturing’s negative potential: "internally neutral";
2. Achieve parity with competitors: "externally neutral";
3. Provide credible support to the business strategy: "internally supportive";
4. Pursue a manufacturing-based competitive advantage: "externally supportive".

Coincided with these four stages, there are also four stages to leverage IT for superior manufacturing performance, which involves four combinations of cross-domain alignments as shown in Table 1. They are summarized in Table 1 and are labeled as: technology defense, technology implementation, strategy implementation, strategy sustenance.

*Technology defense* is a cross-domain perspective that involves the application of IT to the infrastructure of a manufacturing organization and the articulation of the required IT infrastructure. The purpose of implementing IT is to reduce or eliminate "negative" elements in organizational processes and managerial procedures. This type of IT implementation is not unusual to Stage 1 companies who consider their manufacturing organization to be internally neutral, in that its manufacturing process is considered relatively simple and straightforward (and therefore not likely to have much impact on the firm’s overall competitive position). Moreover, the manufacturing technology employed is regarded as relatively standard, and therefore something to be acquired from an outside equipment supplier rather than developed (or even enhanced) within the company. IT is relied upon to provide detailed measurements of and controls over operating performance and plays the role as the primary means for ensuring that manufacturing does not get too far off track.

*Technology implementation* reflects the usage of IT strategy structure to influence key dimensions of manufacturing strategic structure. Beginning with the three dimensions of IT strategy structure, this perspective sorts to identify the best set of strategic options for manufacturing strategic structure and the corresponding set of decisions pertaining to manufacturing strategic infrastructure. The purpose of introducing IT for manufacturing firms in the second stage is to seek competitive neutrality (parity with major competitors) on the manufacturing dimension, rather than internal neutrality. Because that capital investment in IT is regarded as the primary means for catching up to competition, firms in stage 2 tend to purchase IT equipment from the same suppliers who serve major competitors. In a similar vein, their information system technologies are often acquired from external sources such as customers, vendors, strategic alliances, university research groups, or via corporate mergers and acquisitions, all conforming to the standard of the industry practice.

*Strategy implementation* is a cross-domain perspective that involves the assessment of the implications of implementing the chosen manufacturing strategic structure via appropriate manufacturing strategic infrastructure as well as the design and development of the required internal IT strategic infrastructure. A typical firm in the third stage expects its manufacturing organization to provide credible and significant support to its overall competitive strategy. It actively seek to identify longer-term development and trends that may have a significant impact on the success of the manufacturing organization. The "top-down" infrastructure is usually employed in strategic planning. The three dimensions of manufacturing strategic structure are derived from and dictated by a business strategy. This is the most common and widely understood cross-domain perspective as it corresponds to the classic, hierarchical view of manufacturing strategy that many writers suggested, including Skinner (1969, 1978).

*Strategy sustenance* is concerned with the development of manufacturing strategic structure based upon its infrastructure and the implementation of IT strategic structure. The fourth stage of manufacturing information system’s strategic role is when a firm’s competitive strategy is based on a significant degree on its manufacturing capabilities and IT is employed to enhance its manufacturing capabilities.

Information systems implemented in both stages 3 and 4 can be called strategic information systems since IT considerations are incorporated in the firm’s overall strategy. However, manufacturing organizations in stage 3 are still largely regarded as being responsive with respect to their IT, and are simply encouraged to pursue their traditional roles with more ingenuity and somewhat greater resources devoted to IT. In essence, their information systems are not truly strategic. A truly strategic system is the one that supports a fundamental change in the way business is conducted (business process). Information systems that merely automate manual procedures without business process reengineering are unlikely to convey major competitive advantage.

Stage 4 companies not only have a general understanding of the way products, markets, and business processes interact, but these interactions are planned for and coordinated across functions. For example, they know how to use IT to reduce manufacturing lead times and improve delivery dependability. They can also apply IT to improve product quality and reliability, thus yielding lower cost. In short, the design of a strategic information system should be fully compliant with the company’s operations. The system not just combine expert knowledge of the company’s manufacturing and other
relevant systems. In addition, it also contains expert knowledge of decision-making process in the company. Such a system is capable of supporting business change.

Figure 2 illustrates Leavitt's classification of organization as a diamond in which task, technology, people, and structure are interrelated and mutually adjusting. This indicates the complex nature of IT implementation, whose success is possible but requires the recognition that the change process involving task, technology, people, and structure must be explicitly managed.

Because of its size and physical nature, tasks in the manufacturing organization often involve uncertainty and complexity. The stage 3 firm sees this as an apparent information-processing problem and solve it by implementing IT. By comparison, the stage 4 firm seeks to reduce the need for information processing. The example in the beginning of this paper serves well as a demonstration. The control of raw materials inventory and of its movements within the factory are such complicated jobs that advanced computer systems, and computerized devices, are needed to cope with them in an efficient manner. A better alternative might be to remove the conditions that cause inventory to be held.

5.3 Comparison between MRP and JIT

MRP is an approach based upon IT to uncertainty and complexity arises out of the problem of management control in repetitive discrete manufacturing (of cars, air planes, computer). In this situation, a stage 3 firm is very likely to use MRP as the tool to implement its strategy, which contrasts strongly with an operation based approach (JIT) which might be adopted by a stage 4 firm.

MRP is a highly sophisticated information system to manage the complexity and uncertainty that occur in a manufacturing environment. MRP uses the planned production schedule to project the requirements for the individual parts or subassemblies. These requirements are compared with on-hand inventory levels and scheduled receipts on a time-phased basis so that lots can be scheduled to be produced or received as needed. But MRP systems are notoriously difficult to implement and consume substantial resources in the form of computing power and indirect manufacturing labor. Further, because the lead times associated with manufacturing and purchasing could never be accurately predicted, exorbitant lead times are built into a computer system, which merely institutionalizes waste.

JIT is intimately involved in executing manufacturing planning and control systems, particularly on the shop floor control and in purchasing. A key component of JIT is a kanban system. The type of units required by a process and the number required are written on kanbans and used to initiate withdrawal and productions of items through the production process. The use of kanban eliminates the need of information-processing; therefore, there is no need for sophisticated shop floor control systems. Once operations on the shop floor have been streamlined, buffer inventories are eliminated and suppliers will make a delivery only when needed. The JIT approach in execution is focused on simplicity. The intent is to design manufacturing processes, products, and systems that goods flow through very routinely.

6. Conclusion

This paper developed a strategic alignment model for manufacturing information system that specifically addressed the requirements of leveraging the emerging developments in information technologies. This model is based on the need to achieve alignment across structural and infrastructural domains as well as functional integration across manufacturing and IT areas. This model provided an evolutionary process with four different stages which leads to the goal of a world-class manufacturer. From a research point of view, this model can be used to describe and categorize the emerging examples of exploiting IT as a lever for business process reengineering. From a management decision-making point of view, this model serves the purpose of identifying the different alternatives to leverage IT for business process reengineering.

Information processing and IT are becoming critical to many manufacturing organizations who want to be a world-class manufacturer. To be successful with respect to IT implementation, it is imperative that each organization understands the nature of the strategic change it must make, which can be provided by the strategic alignment model presented in this paper. The stage of strategy sustenance tells how important it is to have a systemic perspective toward all kinds of operations in a manufacturing organization.

A poorly designed product, for example, creates complexity that leads to confusion, and triggers demands for engineering changes. Poorly handled engineering changes create wasted material as well as increased reject rates. WORK-In-process, in turn, is often at least partially a function of the amount of unpredictable variation in the reject rate (necessitating backup materials in case the expected amount of good output is not produced). Moreover, work-in-process inventory is both the result of disruptions (confusion) in the plant-caused, for example, by new equipment-and the cause of confusion in itself. Confusion, in short, appears to be linked to a variety of different kinds of change. One of the most important tasks of management, therefore, is to prevent confusion or mitigate the potentially damaging effect of confusion-causing activities. A learning organization with persistent drive to improve its operations is the key to exploiting IT for competitive advantage. The four stages of manufacturing information system's strategic roles proposed in this paper can help managers in various
situations recognize and identify the challenges they face and manage IT as a strategic resource.

References


Figure 1 A strategic alignment model with linkage between manufacturing strategy and I/T strategy delineated.

Table 1
Four Dominant Perspectives on I/T Planning

<table>
<thead>
<tr>
<th>Label</th>
<th>Cross-Domain Perspective</th>
<th>Common Domain Anchor</th>
<th>I/T Planning Method Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Technology Offensive</td>
<td>* IT Strategic Structure</td>
<td>Value Chain Analysis (Porter &amp; Millar 1985)</td>
<td></td>
</tr>
<tr>
<td>(2) Technology Implementation</td>
<td>* IT Strategic Structure</td>
<td>Opportunity Identification (Sharpe 1989)</td>
<td></td>
</tr>
<tr>
<td>(3) Strategy Implementation</td>
<td>Manufacturing Strategic Structure</td>
<td>Critical Success Factors (Rockart 1990)</td>
<td></td>
</tr>
<tr>
<td>(4) Strategy Sustainability</td>
<td>Manufacturing Strategic Infrastructure</td>
<td>Resource-Based Approach (Clemons 1990)</td>
<td></td>
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*Domain Anchor