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Introduction

A major bicycle manufacturer establishes an automated warehouse for incoming components. Robots glide up and down the high-rise bays, selecting bins of components under computer control; the bins are passed on to a conveyor system; they move around on a path determined by barcode scanners that identify each bin and route it to a stock picker. The stock picker removes items for despatch 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 several millions of dollars. However, the expected efficiency of this system has not yet been observed as a result of difficulties encountered with the quality insurance programme for incoming components, and bottlenecks in the successive operations. A manually operated inventory system might do as well or even better.

Another case is a bicycle parts supplier who provides aluminum mixed body-frames for major bicycle manufacturers. Because of the high price in the market, the bicycle style changes according to fashion trends. Hence, its production is limited to small batch. The main task in manufacturing is welding and the company purchased two robots to perform the work. However, the robots could not overcome the technological problems associated with three-dimension movement while welding tasks are performed. These two robots were set aside and left idle.

Volume dependency is the critical success factor for an automatic storage/retrieval system to work. The potential of current automatic welding technologies cannot satisfy the flexibility requirement of the manufacturing process. Perhaps the managers of these two companies 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 do not consider organization design alternative and business process re-engineering while information technology is being implemented, information technology would continue to be a competitive burden.

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Considerable pressure is placed on most organizations to make their operational, tactical and strategic processes more efficient and effective. As in the two cases mentioned above, an increasingly attractive means of improving these processes lies in today's extensive variety of information technologies. In this study, the term information technology (IT) is viewed in a broad sense as it refers to any artefact 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. Jonscher[1] has actually suggested that the appropriate use of IT may be the principal source of future growth for the US economy. However, significant difficulties often plague IT implementation [2-4].

Strategic management of IT

Three major roles for IT are administrative; operational; and competitive[5-6]. The administrative role signifies the scope of IT as the automation of accounting and control functions, which is reasonably well-understood in the conventional literature on management information systems. This role requires the deployment of an efficient IT platform (i.e. 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 IT applications that leverage the information and technological attributes to obtain different sources of competitive advantages in the marketplace. Attention is being increasingly paid to the potential role of IT to shape the basis of competition[7]. However, the emphasis on the competitive role does not exclude the importance of the first two roles. Simon[8] pointed out that design of information systems must consider in depth business processes of the organization. Hayes and Wheelwright[9] also indicated that one of the key success factors of Japanese industries is no separation between strategies and operations. However, a limited consideration of the first two roles for IT 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[10]. 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 IT strategy form parts of a cluster of functional area strategies, e.g. marketing strategy, financial strategy, which complement a higher level of business and corporate strategies.

Subordination of functional strategies to business strategies may be too restrictive to exploit potential sources of competitive advantage that lie at the functional level. Modification of the hierarchical view of the interrelationship between business and functional strategies would add to the flexibility in positioning and implementing strategy as a whole to solve problems of long-term impact for an organization. Functions are being considered as sources of competitiveness and firm-specific advantage. For example, distinctive competences from manufacturing might well determine the survival and growth of manufacturers throughout the 1990s and beyond.

Implementation of IT is critically dependent on the business or the sector on which IT is applied. The work on IT implementation suggests that sector differences are significant[11]. For example, IT has become the means of delivering the goods and services in some sectors, e.g. financial services, airlines and retailing. For a service-oriented business, IT strategy may be synonymous of its product-market strategy. By comparison, managers in manufacturing organizations generally emphasize technology. Therefore, IT is most likely to be used in enhancing manufacturing processes and controlling manufacturing operations. The application of IT in manufacturing organizations either adds to efficiency and precision of manufacturing equipment or facilitates in collecting manufacturing environment information. The former might be referred to as advanced manufacturing technology (AMT) in which flexible manufacturing systems have been mentioned quite often. The latter might be represented by material requirement planning (MRP) systems.

IT implementation with a focus on manufacturing firms will involve interfunctional strategy interactions, i.e. manufacturing strategy and IT strategy. There is a glaring lack of systematic frameworks to conceptualize the logic, scope, and patterns of such interactions. An exception is Henderson and Venktraman's[12] treatment of the business-IT connection.

This need is addressed in this study by offering a strategic alignment model to link manufacturing strategy with IT strategy and to point to alternative strategies for achieving the results that information technology promises. The next section presents a brief background review for manufacturing strategy and its components proposed in the strategic alignment model. Following this, a history of IT strategy and implementation, in addition to the components proposed in the IT strategy is presented. The next section presents the strategic alignment model which involves cross-domain alignment between manufacturing strategy and IT strategy. Based on the model, an evolutionary process including four stages is suggested to enhance manufacturing information system's strategic role. As representatives of two different stages of the process, MRP and JIT are examined to observe their differences in the cross-domain alignment. The final section explains why, in pursuit of a world-class manufacturer, an evolutionary process is necessary for manufacturing organizations in IT implementation. Learning organization is contended to be the driving force in each stage to exploit IT for the competitive advantage.

Manufacturing strategy

As learned from world-class manufacturers, the key point of their achievement is that managers successfully develop manufacturing capabilities. This development critically depends on combining organizational skills with technological ability to produce products better than one's competitors. In addition, their adversary finds it extraordinarily difficult to duplicate this capability behind products. Hence a sustainable competitive advantage can be achieved and maintained. Continually enhancing that competitive advantage requires the employment of a manufacturing strategy[13].

Manufacturing strategies determine how manufacturing is going to reach its objectives within the future environment. The beginning of manufacturing strategy as a field can be traced back to Wickham Skinner's[14] early conceptual work. Since then many operations management writers have contributed to this field. Leong *et al.*[15] is a notable example in an attempt to review, organize and criticize the emerging base of manufacturing strategy literature.

The content of manufacturing strategy consists of a pattern of decisions relating to a manufacturing organization's structure and infrastructure. Decisions of a structural nature resemble the hardware in a computer, which include the following:

- product scope;
- process technology;
- manufacturing alliance; and
- 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[16] such as in the following:

- *End product complexity*. Both BOM (bills of material) structure and the technical difficulties encountered 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 eventually overwhelms the latter.
- *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 flavours for its original product – Coke.
- *Individual product volumes*. Economies of scale used to be the major factor in determining the profit margins of manufacturing firms. It involves the time and frequency of production changeovers. Small production volume often implies a low profit margin; therefore, expansion of product scope is limited. With the advent of flexible manufacturing, however, 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 a production process has been found in previous literature as a variety of seemingly relevant typologies and taxonomies. A later example is represented in the work of Evans *et al.*[17] which used five process categories, i.e. continuous flow, mass (assembly line), batch, job shop, and project. Furthermore, Hayes and Wheelwright[9] believed that product scope and process type would eventually determine many of the characteristics of the productive units.

Unfortunately, the state-of-the-art manufacturing technology has alternated this conventional classification scheme. For example, conventionally discrete parts manufacturing was generally performed in batch or assembly line environment. With the introduction of flexible manufacturing system (FMS) concepts, however, 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 study develops the notions by Chiantella[18]. This dimension is a composite of three underlying variables:

(1) mechanization level;

(2) systemization level; and

(3) interconnection level.

The level of mechanization is classified as manual, machine, fixed programme, and programmable control. The level of systemization is presented in the following order: data collection, event reporting, tracking, monitoring, guide, and control. Chiantella[18] determines the level of automation for a particular process technology as a composite function of the level of mechanization and the level of systemization.

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, systemization, and interconnection, the focus here is placed on the dominant characteristic of an entire 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. Organizing manufacturing operations is essentially the choice of a structural mechanism.

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

On the other hand, infrastructure refers to the management policies and systems which determine how the hardware (structure) is managed. A parsimonious set of dimensions specifies infrastructure as manufacturing administration, processes, and skills.

Manufacturing administration includes manufacturing organizational structure, roles, and reporting relationships, which contains the following:

- human resource policies and practices, including management selection and training policies;
- quality assurance and control systems;
- production planning and inventory control systems;
- new product development process;
- performance measurement and reward systems, including capital allocation systems; and
- organizational structure and design.

Processes refer 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 crucial. Information flows serve not only to co-ordinate 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.

Co-ordination between manufacturing administration, processes, and skills will facilitate an organization's operations as well as eliminate bottlenecks. The key point is the manufacturing firm's processes – where the organization's material flows and information flows are delineated and the manner in which the work is performed is dictated. The design of processes in turn determines the nature of people's jobs and how the people who perform these jobs are grouped and organized. This actually is what administration is involved with. Skills address the capability of the individual and the capability of the organization in performing tasks. Well-integrated processes can reduce the company's uncertainty and complexity, and therefore should pay a significant amount of attention to administrative decision rules, flow patterns, and task designs. The notion of business process re-engineering (BPR) which looks into the analysis of design of processes in association with other infrastructural elements would assist managers to achieve dramatic improvements in critical measures of performance[19].

Information technology strategy and implementation

The connection between strategy and IT has not been clearly articulated with respect to a finite set of concepts, analytical framework, and normative prescriptions. The strategic role of IT from a manufacturing perspective can be referred to as technology push[20]. Two issues deserve special mention, i.e. one is cost-performance trends and connectivity capabilities. Rapid advances in the various components of IT have resulted in continuous improvements in price-performance ratio in recent years. Firms are now capable of designing and deploying IT platforms as competitive weapons at a fraction of the cost that prevailed only a few years ago. The second issue is the increased connectivity capabilities over time. Sophisticated forms of connectivity involving multiple types of hardware, software, and communication systems can now be developed.

Analogous to manufacturing strategy, IT strategy is conceptualized in terms of structure and infrastructure. Decisions of a structural nature contain three dimensions:

(1) *System competences*. The focus is placed on those distinctive attributes of IT competences, which are often emphasized by an organization in designing and operating its IT and add value to its product and services. Principle components are costs of information processing, flexibility to provide different classes of information, and capability of providing specialized information.

(2) *Technology scope*. It refers to the types and range of IT 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 must be based on the strategy of the organization.

(3) *IT alliance*. These are the choices of structural mechanisms available to organizations to obtain the required IT 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 proprietary value-added networks in electronic data interchange) as well as strategic choices pertaining to development of partnerships to exploit IT capabilities and services (e.g. outsourcing an organization's data centre operations to another organization).

Analogous to the infrastructure of manufacturing strategy, the infrastructure of IT strategy includes the following:

(1) IT architecture comprises the following four items:
   - Computing – the information processing hardware and its associated operating system software.
   - Communication – the telecommunications networks and their associated mechanisms for interlinking and interworking.
   - Data – the data assets of the organization and the requirements of use, access, control and storage.
   - 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 IT 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 IT strategic infrastructure within the organization.

Exploiting IT for competitive advantage within organization is likely to face implementation problems. Past research has categorized IT implementation problems into factors research, process research, and political research[21]. Among these three approaches, process research is adopted in this study. Process research examines social change activities and suggests that implementation success occurs when: commitment to change and the implementation effort exists, extensive project definition and planning occurs, and management of the process is guided by the organizational change theories[22]. Lewin-Schein framework is a notable example of the organizational change theories. The framework looks to a progressive process which aims at accomplishing organizational transformation through the lens of organizational development. Three stages are involved in the process. The unfreezing stage is that of softening current management attitudes and beliefs. The change stage is switching managers' thinking by discovering new emphases, threats or opportunities. Finally, the refreezing stage involves reassessing management practices to implement new thinking.

The strategic alignment model

Bivariate fit and cross-domain alignment

The proposed model is depicted in Figure 1. This model covers both manufacturing strategy and IT strategy, each of which 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.

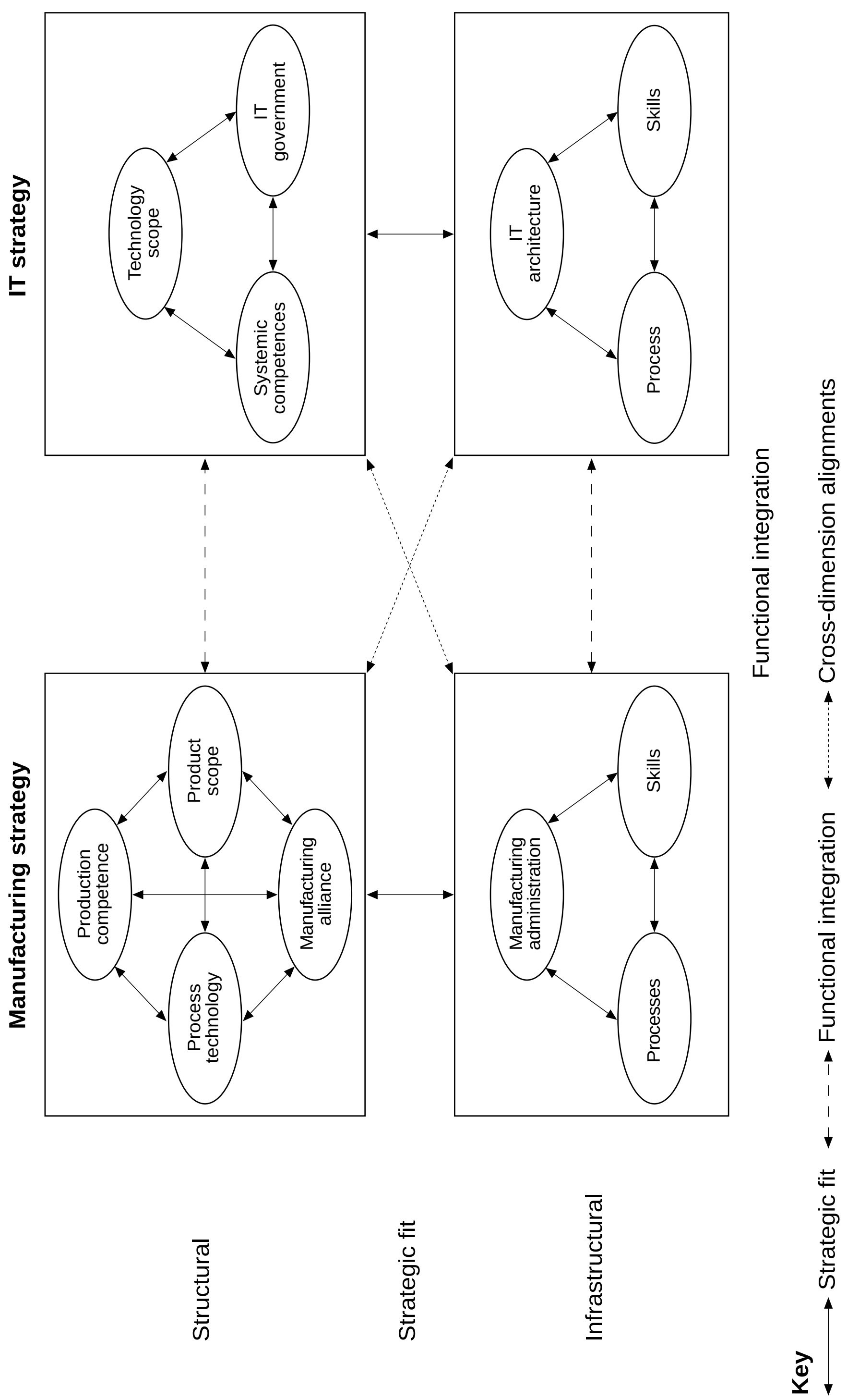

Figure 1.
A strategic alignment model with linkage between manufacturing strategy and IT strategy delineated

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 infrastructure;

(2) bivariate fit between IT strategic structure and infrastructure;

(3) bivariate fit between manufacturing strategic structure and IT strategic structure; and

(4) bivariate fit between manufacturing strategic infrastructure and IT infrastructure.

The bivariate relationship between manufacturing strategic structure and infrastructure has been a dominant theme in manufacturing strategy research[23-24]. As learned from the experience of leading Japanese and German manufacturers, systematically focusing on, and refining the details of their manufacturing operations can provide a firm with a competitive advantage that is difficult for competitors to overcome if they have not yet developed a similarly effective infrastructure. The structure segment covers a set of decisions where issues relating to infrastructure can be addressed. The major source of long-term competitive strength in manufacturing lies in developing a strong infrastructure which reinforces a strong structural base.

Correspondingly, the bivariate relationship between information strategic structure and infrastructure accentuates the requirements to interconnect an organization's IT usage in manufacturing with its approach to managing the information system (IS) function in its organizational context. These two relationships represent the classic strategy formulation-implementation perspectives for the two strategies considered here, i.e. manufacturing strategy and IT strategy.

In contrast, the other two bivariate relationships link the domains horizontally. The link between manufacturing strategic structure and IT strategic structure reflects the capability to leverage IT strategic structure to both shape and support manufacturing strategic structure. This normally occurs when AMT (advanced manufacturing technologies), which possess a tremendous amount of information processing capability, are used to reinforce manufacturing strategic structure, and hence play the competitive role of IT function[25].

Correspondingly, the link between manufacturing strategic infrastructure and IT infrastructure reflects the requirement to ensure internal coherence between the organizational requirements and expectations on the one hand, and the delivery capability within the IS function on the other hand. This is particularly relevant because the IS function is often viewed as "the business within a business"[26]. A management framework is required to facilitate the organization in running its IT business. The business processes in manufacturing strategic infrastructure are expected to have a significant impact on this framework.

A major benefit of the bivariate fit perspective lies in its simplication 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.

Manufacturing information system's strategic role

If the objective of a manufacturing firm is to become a world-class manufacturer, not only does the firm need to employ IT but should it also consider its overall impact on the organization. In light of manufacturing strategy, it may be appropriate for a manufacturing organization to follow a sequential process in the development of its manufacturing strategy. Hayes and Wheelwright[23] suggested 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 one stage to an adjacent one. These four stages of development in manufacturing's strategic role are:

(1) *Minimize manufacturing's negative potential*: "internally neutral". The manufacturing organization can not handle strategic manufacturing issues. Outside experts are called in to offer consulting services on internal management control systems. The focus is placed on manufacturing administration and processes in the manufacturing strategic infrastructure.

(2) *Achieve parity with competitors*: "externally neutral". An industry-wise perspective is taken. The primary objective involves seeking parity with major competitors on the manufacturing dimension. The primary means to obtain a competitive advantage is through capital investment to upgrade manufacturing equipment. This corresponds to the dimension of process technology in manufacturing strategic structure.

(3) *Provide credible support to the business strategy*: "internally supportive". Manufacturing strategy is dictated by business strategy and manufacturing strategic infrastructure is governed by manufacturing strategic structure). A top-down (from structure to infrastructure) approach is taken in developing manufacturing's strategic role.

(4) *Pursue a manufacturing-based competitive advantage*: "externally supportive". The initial point lies in the dimension of processes in manufacturing strategic infrastructure. BPR is employed to create new manufacturing practices and technologies. Considerations in the manufacturing strategic infrastructure precedes those in the manufacturing strategic structure. A bottom-up (from infrastructure to structure) approach is taken in developing manufacturing's strategic role.

The management in stage 1 companies regards manufacturing as neutral at best and seeks simply to minimize any negative impact it might suffer from. Such companies believe that their product designs are so extraordinary or their marketing organizations so powerful; hence they could occupy a market niche which is immune from immediate competitors. The focus of manufacturing strategy is production without surprise. However, sources of competitive power derives from the capability to meet the cost, quality, dependability, flexibility and time standards achieved by one's competitors. Stage 2 companies seek to satisfy the standards imposed by their major competitors. Such companies buy production equipment from the same suppliers and adopt similar manufacturing processes as their competitors do. They also employ the same managerial approach in manufacturing administration. However, imitation alone does not result in distinctive production competence.

Companies which are searching for a competitive strategy which is different from that of most of their competitors expect their manufacturing organization to be capable of providing credible and significant support to the overall competitive strategy. Such companies evolve to stage 3, in which a co-ordinated set of manufacturing structural and infrastructural decisions is tailored to their specific competitive strategy. For world class (stage 4) companies, success depends on how one excels over other competitors in the market. Such companies' competitive strategy is based to a significant degree on their manufacturing organization. They employ BPR to refine their manufacturing strategic infrastructure, and have the capability to use their equipment more effectively than their competitors use theirs.

Here, stage 1 or "internally neutral" companies are associated with Lewin's unfreezing stage. Stages 2 and 3, "externally neutral" and "internally supportive" companies, are associated with Lewin's change stage. Stage 4 or "externally supportive" companies are associated with Lewin's refreezing stage. In association with this progressive process in developing manufacturing's strategic role, the IT's strategic function for a manufacturing organization can also be established by following those stages. In particular, a specific cross-domain alignment is proposed to show in each stage how IT is leveraged for superior manufacturing performance. This is because information is only part of organizational decision-making process. Evolutionary and incremental change might find least resistance in usually complicated organizational decision processes. These four types of cross-domain alignment are summarized in Table I and are labelled as: technology implementation, technology exploitation, strategy implementation, and strategy sustenance. IT planning method examples are also shown[27-31].

Technology implementation, as depicted in Figure 1, is concerned with the strategic fit between the external articulation of IT strategic structure and the internal implementation of the processes with respect to the IT strategic infrastructure, with corresponding impact on the manufacturing strategic infrastructure. This perspective calls for integration of IT strategic structure and infrastructure, and its subsequent application to the processes in manufacturing strategic infrastructure. The competitive role of IS function is minimized because only operations improvement is sought in this approach. The purpose of implementing IT involves either reducing or eliminating "negative" elements in organizational processes and managerial procedures. Examples of analytical methods include: end-user need surveying[32], service level contracting[27] and architectural planning[33].

Stage	Cross-domain perspective	Common domain anchor	IT planning method example
(1) Technology implementation	* ↓ ←	Strategic structure	Service level contracting[27]
(2) Technology exploitation	← * ↓	Strategic structure	Opportunity identification[28] Value chain analysis[29]
(3) Strategy implementation	* ↓ →	Manufacturing strategic structure	Critical success factors[30]
(4) Strategy sustenance	↑ → *	Manufacturing strategic structure	Resource-based approach[31] Business processes re-engineering[19]

Note:
* = Domain anchor

Table I.
Four dominant perspectives of IT planning

This type of IT implementation is typical to stage 1 companies who consider their manufacturing organization to be internally neutral, in that its manufacturing process is considered to be 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 on to provide detailed measurements of and controls over operating performance and functions in the role as the primary means for ensuring that manufacturing does not stray away from its original objective.

Technology exploitation 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 seeks to identify the optimum set of strategic options available for manufacturing strategic structure and the corresponding set of decisions pertaining to manufacturing strategic infrastructure. Its major objective is concerned with the exploitation of IT capabilities to affect new products (i.e. product scope) and process technology, influence the key attributes of manufacturing strategy (i.e. production competences) as well as develop new forms of relationships. (i.e. manufacturing alliance). This perspective allows for modification of the manufacturing strategic structure via IT capabilities.

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 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, e.g. customers, vendors, strategic alliances, university research groups, or via corporate mergers and acquisitions. All of these sources conform to the standard of the industrial practice.

The current industrial practice is focused on the bivariate fit between manufacturing strategic structure and IT strategic structure. However, the effectiveness of IT capabilities is seriously limited without directing attention to the redesign of internal operations. Exploiting full potential of IT capabilities is hampered by the manner in which it is operated in North America and Europe[34-36]. Managers steeped in the values and assumptions of high volume standardized production are not always concerned with IT's strategic potential.

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 seeks to identify longer-term development and trends that may have a significant impact on the success of the manufacturing organization. The "top-down" approach is often 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 classical hierarchical view of manufacturing strategy that many writers have suggested, including Skinner[15,37].

Strategy sustenance is concerned with the development of manufacturing strategic structure based on 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 to 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 referred to as 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 manner in which business is conducted. Information systems that merely automate manual procedures without business process reengineering are unlikely to convey a threatening competitive advantage.

Stage 4 companies not only have a general understanding of the manner in which products, markets, and business processes interact with one another, but these interactions are planned for and co-ordinated 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, thereby yielding a lower cost. In short, the design of a strategic information system should fully comply with the company's operations and is capable of supporting its change. The system does not simply combine expert knowledge of the company's manufacturing with 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.

Implementing IT in stage 3 requires functional integration between manufacturing strategic infrastructure and information technology strategic infrastructure. This is a complicated matter since there are six strategic components are involved; however, a simple approach is capable of accounting for the interaction involved in this situation. As indicated in Figure 1, the processes components refer to sequences of tasks to be performed. Therefore, the functional integration recognizes that task, technology platform, and worker's skills are interrelated and mutually adjusting. As a result, the change process involving these three elements 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 solves it by implementing IT. By comparison, the stage 4 firm seeks to reduce the requirement for information processing. The two cases used as illustrative examples in the beginning of this paper reflect the viewpoint that investment in IT alone will not solve the problem. In essence, the control of raw materials inventory and of its movements within the factory are such complicated tasks that advanced computer systems, and computerized devices, are required to cope with them in an efficient manner. A better alternative might entail removing the conditions that cause the inventory to be held.

Comparison between MRP and JIT information systems

Material requirement planning (MRP) is an approach based on IT to handle uncertainty and complexity which arises out of the problem of management control in repetitive discrete manufacturing (of cars, aeroplanes, computers). In this situation, a stage 3 firm is quite likely to use MRP as the tool to implement its strategy. On the other hand, a stage 4 firm might adopt JIT, which is an operation-based approach and does not require a significant amount of resources investment in IT.

MRP is a highly sophisticated information system which manages 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 required. Material requirement computation along with updating time-phased data have placed a tremendous amount of pressure on information processing. According to a general consensus among all practitioners that, in spite of all the effort to use MRP as a scheduler, MRP is actually a databank[38].

Providing the right product, in the right quantity, at the right time and at the right place is at the heart of JIT. 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 are used to initiate withdrawal and productions of items through the production process. The use of *kanban* eliminates the requirement of information-processing; therefore, there is no need for sophisticated shop floor control systems. Once operations on the shopfloor have been streamlined, buffer inventories are eliminated and suppliers will make a delivery only when required. The JIT approach in execution is focused on simplicity. The intent is to design manufacturing processes, products, and systems in which goods flow through quite routinely.

Strategic alignment perspectives of MRP and JIT

Some fundamental differences arise between MRP and JIT, each representing an entirely different management philosophy[38]. MRP employs the information-processing capability to reinforce the traditional comand-and-control (top-down) approach to management. Central planning is essential to implementation of the top-down approach. Through elaborate planning exercises, senior managers determined the businesses in which they wanted to be, how much capital they should allocate to each, and what returns they would expect the operating managers of these businesses to deliver to the company. Large staffs of corporate controllers, planners, auditors, and information system managers monitor the data about divisional performance, and intervening to adjust the plans and activities of operating managers. The part of manufacturing strategic structure was actually determined largely by top management. Acquiring review by top management is necessary in the decision hierarchy. In light of the fact that decisions related to process technology, production competence, product scope, and manufacturing alliance usually involve capital investment and are of long-term strategic implications.

The issues associated with manufacturing strategic infrastructure were considered to be operational and delegated to operating managers. Questions having to do with workforce, product quality, production planning and control, related organizational structure, etc., in this view, are operating considerations only and are considered of secondary importance to the company.

For the purpose of better planning and control, work was broken down into pieces. Managers could ensure consistent and accurate work performance and their superior could do the same. Since work is divided into simple tasks, complex processes are demanded to knit them together. MRP generates the information required to coordinate various activities in departments: telling people what to do and when to do it. Detailed instructions are conveyed to the factory floor indicating how people should respond under every eventuality.

Built on the processes, manufacturing administration – how operations are controlled and checked, how performance of workers is evaluated – is the bureaucracy that provides the mechanism of all management activities. Fragmented processes lead to significant administration overheads.

Automating existing processes with information technology will not reduce waste. On the other hand, an information-technology approach adds to it by burdening an already inefficient system with the cost of computation. In the final analysis, MRP is actually an aid to planning. MRP itself is not a planning technique because it cannot generate, evaluate, and select scheduling alternatives in the face of limited productive resources. It will not alter the existing processes. With its information processing capability, MRP appears as a simulation tool which allows managers to examine the consequences of their production planning decisions.

JIT begins in re-engineering the processes in manufacturing strategic infrastructure. The focus of JIT is on material velocity so that continuous flow production can be achieved. This task is achieved through the process design with respect to manufacturing cells and the stabilization of production schedules. The result is simplified processes with routine execution. Detailed tracking is not required since work must flow through the factory quickly. A related idea is in the responsiveness of the system. In a company with low manufacturing lead times, the manufacturing processes are designed with enough surge capacity to take on a fairly mixed set of products, and some variation in demand for the products.

Simplified, integrated processes reduce the requirement of administration overheads. Checks and controls are reduced. Unlike MRP systems, less information is processed purely for co-ordination purposes because JIT systems are simpler, more visual, and controlled locally. However, substantial information is required on the factory floor to recognize operating patterns, identify cause-and-effect relationships, and diagnose and eliminate problems. This would require broadly skilled people for systematic problem solving.

Information technology is part of the re-engineering effort in JIT approach. Advanced manufacturing technologies, built around low-cost computing power, new sensors, and advanced software to link them with high performance equipment, can contribute substantially to the continuous-flow environment. The new information technologies enable management to expand the domain of factory-floor personnel. People on the floor can now acquire data and, with the facilitative help of computerized analysis, transform those data into improved process knowledge. The sequence (data collection-process knowledge-improvement planning-action) naturally repeats itself and eventually leads to a learning organization.

In the context of the strategy alignment model, the comparison between MRP and JIT as top-down and bottom-up strategic planning approaches is presented in Table II.

Conclusion

A strategic alignment model has been developed in this study for a manufacturing information system that specifically addresses the requirements of leveraging the emerging developments in information technologies. This model is based on the requirement to achieve alignment across structural and infrastructural domains as well as functional integration across manufacturing and IT areas. This model provides an evolutionary process with four different stages which leads towards the goal of a world-class manufacturer. From a research perspective, this model can be used to describe and categorize the emerging examples of exploiting IT as a lever for BPR. From a management decision-making perspective, this model serves the purpose of identifying the different alternatives to leverage IT for BPR.

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, each organization must understand the nature of the strategic change it must make, which can be provided by the strategic alignment model presented in this study. The stage of strategy sustenance tells how crucial it is to have a systemic perspective towards all kinds of operations in a manufacturing organization.

A stage 4 company requires a highly autonomous and self-conscious community in the organization to nurture a proactive problem-solving attitude. The amount of effort to achieve such an objective in the short term could be so enormous that would be easily overwhelmed by the organizational inertia. In the case of JIT, it takes careful design and commitment by both management and workers for continuous flow manufacturing to be effective. Without sufficient manufacturing capability, JIT production can not realize. Based on experiences of world-class manufacturer in the industrialized nations, the

Strategic dimension	JIT-type system	MRP-type system
Manufacturing strategy		
Manufacturing administration Human resources policies[39]	A cross-trained and highly skilled workforce with continuous learning and improvement programmes	Mindful of control on labour costs, the management does not place a high priority on human resources development
Quality assurance[40]	Encouraging participation of the workforce in problem solving by motivating workers to solve quality problems	Emphasizing an acceptable quality level, the primary focus is placed on statistical techniques
Production planning and inventory control[41]	Uniform plant load is the focus of production planning. Only keep material at work-centre stockpoints	Time-phased order point is used to create planned order releases of end items. Inventories are reduced to planned levels. Inventories are built in stockrooms to level out capacity requirements
Product development process	Overlapping problem solving involves parallel and integrated activity[42]	Each function is expected to play a specific and limited role. The cross function information transmission involves a sequential linkage[13]
Performance measurement	Group consciousness is an important factor that leads to participative management style, marked by mutual respect and a mutual desire to work towards common interest[43]	Evaluation of performance is based upon the merit rating system. The system motivates people to do their best, for their own good[44]
Organizational design	The organizational structure nutures lateral relations, co-ordinated and communication among functions[45]	Centralized, staff-dominated planning and control systems[46]
Process[17]	The kanban card system dictates the material flows. Little paperwork is required except for cards	There is a requirement for sophisticated inventory control systems and WIP tracking
Skills[47]	The concept of whole person develops flexibility in words. They are trained to take on many tasks. Periodical on-the-job training is prevalent	Workers follow job specifications that are defined narrowly and precisely
Manufacturing alliance[48]	Schedule vendors almost as one's own plant and work closely with a small number of vendors	Vendor selection is based on the notion of maintaining a competitive supplier base to achieve the least invoice cost
Process technology	Flexibility and responsiveness are emphasized in the design of the process. Material must flow through in short cycle times and the system allows more flexibility to take on a fairly mixed of products, and some variation in demand[35]	Process technology tends to be viewed simply as a means of meeting required output targets and performance goals[49]

(*Continued*)

Table II. Comparing stage 3 and 4 firms that employ JIT and MRP as strategic manufacturing information systems

Strategic dimension	JIT-type system	MRP-type system
Product scope[50]	Economy of scope: have the benefits of product variety and short lead time without incurring increases in costs due to lack of specialization	Rule of volume dependency: produce products in high volume is the major concern regarding productive capacity
Production competence[51]	Quick response: • Able to market and provide the product faster than the others • Quick problem-solving capability • Reduced inventory, scrap, and obsolescence	• Scheduling order releases in sequence • Reducing inventories to planned levels • Reducing lead times
Information technology strategy		
IT architecture[38]	A simple system without strong demand for computing time	Generation of MRP schedules takes a lot of time. The vast majority of the time is spent on internal shuffling of data: totally input/output bound
Process[52]	The floor personel is responsible for making decisions related to the shopfloor	
	The development of lateral relations permits its companies to make more decisions and process more information without overloading hierarchical communication channels	Centralization of key decisions
Skills[53]	A competent workforce is required	A strong central planning staff is required
Technology scope[54]	The implementation of JIT requires operating conditions of constraint processing times, efficient movement of materials, and high motivation among others. the performance of JIT deteriorates rapidly under non-ideal conditions	MRP relies heavily on the investment in vertical information system. The shopfloor control system collects status information on WIP and reports back to the order releasing mechanism in MRP. The need for data integrity is clear, as is the need for promptness of reporting
System competences[55]	Sever the link with computer: • The visual kanban system keeps inventory quantity fixed, and updates priority • The rate-based synchornized production schedule is emphasized	Considerable computing power is required to do three principal tasks of MRP system: • Planning and controlling inventory • Detailed capacity planning • Priority planning on the shopfloor Therefore the cost of information processing is relatively high

Table II.

development of manufacturing capability is often a time-consuming process. Therefore, the passage from stage 1 to stage 4 should be processes of gradual change rather than steps of a giant leap.

Rationalization of organizational processes is the focus in stage 1 which includes setting up patterns of information flow, criteria of performance review, and worker's job description. From this perspective, the objective of rationalization is for internal operations only. The companies in stage 1 tend to use IT to enhance or improve what they are already doing. In other words, the presence of IT is primarily for efficiency focus under the existing processes.

In stage 2, the company looks outward and compares with other competitors in the market. The improvement effort starts in learning a new technology and employing industrial practices that are considered state of the art in the industry. Through the learning process, rationalization of internal operations can be furthered. The primary role of IT in this stage is to permit the management learn the possibilities that latent in technology could trigger solutions to productivity problems. This is quite necessary because AMT based on IT typically takes a long time for a company to adjust.

A stage 3 company attempts to formulate a long term strategic plan, and most important of all, linkage between strategic policy and manufacturing related operations is emphasized. Given the association between manufacturing system operations and their information processing requirement, IT functions in the supporting role for the system. In the case of MRP, a company in stage 3 is termed as a Class A MRP user. In a Class A company, the MRP system provides the working plan that sales, finance, manufacturing, purchasing, and engineering people follow. This system becomes the formal system which guides all kinds of operation in the company.

In stage 4, IT is used to innovate processes. Various information technologies, e.g. data base and network, are implemented to form a distributed computing environment, in which a decentralized decision making architecture can be made possible. The processes are simpler than those of the centralized system outlined in stage 3. The information only tracks a few key variables at local level; line operators are directly responsible. Decision making is done primarily at floor level. The role of management is to set direction, establish cormmtment, and allocate resources. JIT production is a paradigm of this decentralized framework.

A learning organization with a persistent drive to improve its operations is the key in exploiting IT for competitive advantage. The implementation of IT in the first three stages provides opportunities to understand manufacturing system in depth and the potential of IT could be utilized for the manufacturing system intended. This effort eventually leads to a transformation of what has been learned previously into attributes and characteristics of the four strategic domains. Based on those structural and infrastructural factors, innovating ideas are sought to obtain a sustainable competitive advantage for manufacturing firms. In the final analysis, the four stages of manufacturing information system's strategic roles proposed in this study can assist managers in various situations to recognize and identify the challenges they face and manage IT as a strategic resource.

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