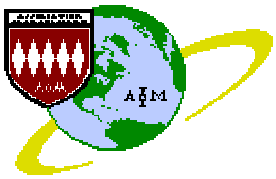

Journal of Information Technology Management

ISSN #1042-1319

A Publication of the Association of Management

INFORMATION TECHNOLOGY INFRASTRUCTURE: A HISTORICAL PERSPECTIVE OF FLEXIBILITY

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ABSTRACT

In today's business environment successful information technology (IT) applications are expected to grow and adapt to new market conditions. IT vendor tout their new products as having such characteristics as open source code and multiple platform adaptability. But as with previous business processes and systems the successful IT application is in need of the basic attribute of flexibility. Utilizing three suggested dimensions of flexibility and the strategic flexibility framework this paper examines the foundation and the concept of IT flexibility and the resemblances found when compared to the concept of manufacturing flexibility and competitive advantage.

Keywords: information technology, manufacturing flexibility, organizational effectiveness

INTRODUCTION

The business landscape of today requires new and innovated applications in the areas of marketing, manufacturing, and customer service to meet growing customers' demands. As organizations strive for competitive advantages with their applications, the concepts of "time to market" and "flexibility" has become significant attributes. This new business environment has produced concepts such as campaign management systems (CMS) for marketing, supply chain management (SCM) for manufacturing, and customer relationship management (CRM) for customer service. CMS may be viewed as a marketing system that assists in the planning, product/service definition, scheduling, and execution of a marketing campaign. SCM is often viewed as the support system to aid manufacturing in the efficient production and delivery of goods. CRM can be defined as a technological mechanism used to enhance the customer's relationship with an organization. While all of these relatively new managerial system tools are technologically based, they seem to have a single inherent quality, that of flexibility. That flexibility is believed to be the basis of a competitive advantage.

But the concept of flexibility that many of these applications are built upon is not new, and actually evolved from old concepts. This paper investigates the foundation

and components of flexibility found in the historical manufacturing sector, and employ those components in the context of defining information technology environments for competitive advantages. Specifically, we will attempt to quantify and define information technology competitive environments as they relate to information technology infrastructure flexibility (ITIF).

To achieve this objective we must first define the concepts of competitive advantage (CA) and sustainable competitive advantage (SCA). Secondly, we will discuss the dimensions of flexibility, followed by the review of comparative manufacturing flexibility. Next, the concept of IT as a set of components is examined utilizing an example of electronic data interchange. The result of these deliberations is the identification of the dimensions of ITIF, and discussion about ITIF and competitive advantages.

COMPETITIVE ADVANTAGE

According to Porter [46], competitive initiatives centered around technical superiority, product or service quality, and comprehensive customer service yield the highest potential for a longer-lasting competitive edge. These longer-lasting competitive initiatives dramatically increase the benefit period for the implementing firm, but to secure an open ended benefit period, a firm must pursue a sustained competitive advantage (Thompson and Strickland, [53]). Specifically, Rumelt [48] defined sustained competitive advantage as existing only after the efforts of rivals to duplicate the advantage have failed and ceased. Sustained competitive advantage is obtained by firms implementing strategies that exploit their internal strengths, through responding to environmental opportunities, while neutralizing external threats and avoiding internal weaknesses (Barney, [3]).

Competitive advantage can be defined as the implementation of an action creating value that is not being simultaneously created by any current or potential competitors (Barney, McWilliams, and Turk, [4]). A firm has a competitive advantage whenever it has an edge over rivals in attracting customers and can defend against the competitive forces of: rivalry among sellers, substitute products or services, potential new entrants to the field, and pressures from suppliers and buyers (Porter, [46]). The search for a competitive advantage requires the continual examination of both internal and external positions of a firm's opportunities such as emerging new technologies, and threats such as changing buyer needs and demands (Thompson and Strickland, [53]).

To achieve a measure of competitive advantage, the action of the firm must acquire or possess some exploitable resource or capability that is rare among competing firms (Barney, [3]). An organization's capabilities and resources are defined by all of the assets used to develop, manufacture, support, and deliver products and services to customers (Daft, [18]). These resources can be categorized into areas of human, organizational, or technical investments (Beker, [5]; Tomer, [54]; Williamson, [60]).

Competitive advantage, according to Thompson and Strickland [53], is nearly always achieved by successful offensive moves by a firm against its rivals. Types of offensive moves available include such tactics as: mounting a preemptive strike that involves being the first mover to create a position difficult for rivals to duplicate, exceeding a competitor's strengths by reducing the cost of delivering goods and services to customers, and capitalizing on the weaknesses of competitors by supplying a broader range of offerings and support services (Kotler, [36]; MacMillian, [42]).

SUSTAINABLE COMPETITIVE ADVANTAGE

Even if an organization achieves some measure of competitive advantage, the benefits enjoyed are subject to decay as rivals successfully replicate the advantage in the market, thus reducing that specific parameter to being just another base line key success factor for that market (MacMillian, [42]). Thompson and Strickland [53] define base line key success factors as strategic related approaches, actions, competitive capabilities, and business outcomes that every firm within a market must be competent at in order to be minimally competitive and financially successful. Vitale [58] specifically addressed the IT base line key success factors, in stating that "IT may provide limited advantages to the innovator before being readily copied by competitors". In the arena of IT applications, as with other goods or set of services that are universally available by a large number of competing firms, the opportunity of that good or service alone to be a source of competitive advantage for a single firm is very low (Wernefelt, [59]).

THE DIMENSIONS OF FLEXIBILITY

The concept of flexibility can be traced back to the study of oscillations in the business cycle (Hart, [25]; Kindleberger, [32]; Knight, [37]; Lange, [38]). Duncan [20] defines flexibility as the ability of a resource to be used for more than one end product, with ITIF measured as the degree of sharability and reusability. Evans [21] suggested the issue of elasticity, allowing a firm to revert back to a preexisting norm after accommodating some temporary condition. Other related terms such as robustness, slack, pliability, and agility suggest differing levels of meaning as to yielding to change pressure, capacity of adoption, and susceptibility of modification (Bonder, [8]). Leeuw and Volberda [39] offered the perspective of flexibility as a function of the degree of control capacity of management. The general terms associated with flexibility that have been previously described as mobility, agility, responsiveness, and suppleness will also be included.

The process of the reviewing the terms associated with flexibility in both the areas of manufacturing and information technology systems suggests that they may not be a singular concept, but instead represent different factors of flexibility based on the firm's perspective. Thus we propose that flexibility of a system may be best represented by three dimensions or influences. The three dimensions are defined as: 1) slack, the degree of excess capacity, under utilization or salability, 2) adaptability, the degree of versatility, openness, robustness, and 3) intensity, the degree of repetitiveness and frequency of changes in a parameter.

Individually each dimension may be insufficient to represent the construct of flexibility, but collectively it is suggested that these three dimensions can adequately address both the manufacturing and technology flexibility parameters of a system. In example given a system that has a sufficient reserve of adaptability and intensity, but operates at 100 % utilization (zero slack) would have very little room to accommodate system changes.

Borrowing from the discipline of electrical engineering the three dimensions of flexibility can be graphically represented by a modified sine wave as shown in Figure 1. The three dimensions of flexibility are defined as slack, adaptability, and intensity. Slack is identified as the graphical component "S", this represents the footprint or the width of the horizontal plane where the aptitude of the parameter can expand or contract as demanded. A narrow footprint denotes a minimal amount of slack, whereas a wide footprint denotes a greater degree of capacity. Adaptability is identified as the graphical component "A", as with the amplitude on the vertical plane of a sine wave the higher the crest the greater degree of openness or acceptance to variation without change. Intensity is identified as the graphical component "I", as with the frequency on the vertical plane of a sine wave the greater number of cycles per unit of time the greater number of required adaptations by the system.

COMPARATIVE MANUFACTURING FLEXIBILITY

To assist in better understanding the concept of flexibility in information technology infrastructures this research borrows the parameters of flexibility found within the realm of manufacturing. To support the linkage between manufacturing environments and information technology infrastructures we first incorporate the value chain analysis work of Porter [46], where similarities exist between the two environments as they are both associated support activities.

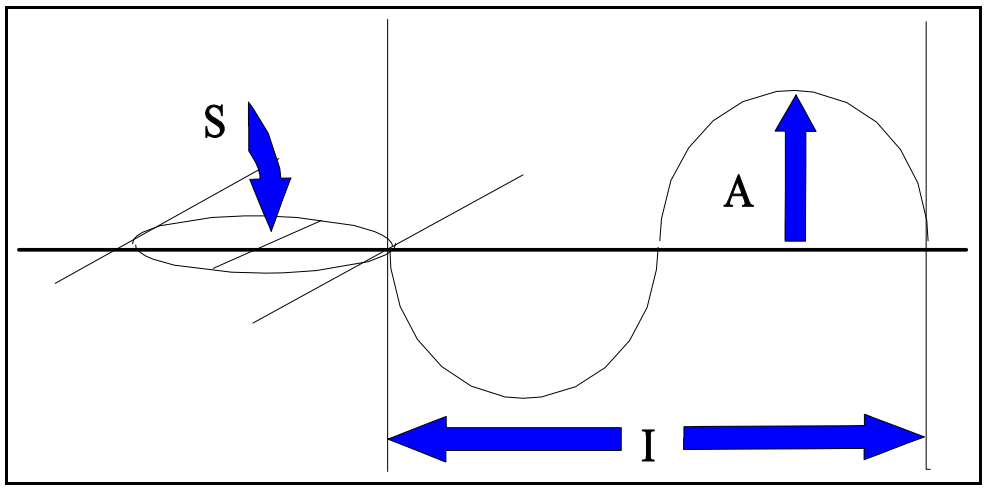

FIGURE 1: Graphical Representation of the Dimensions of Flexibility

Though an information infrastructure may be more closely identified as having the attributes of a service industry (human factors, timeliness, non conformity, and facility), opposed to that of a strict manufacturing environment, the information structure contains many of the same internal factors relevant to flexibility (Mitra, [45]). This is noted by Pyoun and Choi [47] where it is suggested that flexibility is the capacity to cope with internal and external change, and differentiated between inherent current flexibility and flexibility attained after implementation (Chandra and Tombak, [14]; Gupta and Gupta, [23]; Jaikumar, [29]; Sethi and Sethi, [50]).

As all systems have some defined existing capability to serve the needs of the organization, this existing capacity can include the potential to address some degree of changes in the requirements of that system, and this is termed as potential flexibility (Hyun and Ahn, [27]). Four distinct categories can be associated to the concept of manufacturing potential flexibility; incremental, tooling, interchange, and software. Of these four the first three are applicable to the concept of flexibility in information infrastructure: 1) Incremental, as the ability to increase or decrease capacity as needed, 2) Tooling, the ability to modify output or process within the confines of the operation, and 3) Interchange, the ability to reschedule processes or interchange components without disrupting the output.

Another parameter of manufacturing flexibility that is found to be applicable to ITIF is that of realizable flexibility, where physical characteristics, operating polices, and management practices create elasticity within the system (Gupta and Buzacott, [22]). This parameter includes the components of investment, control, and adaptation. Within the component of investment are the factors of change, where investment retains the capability to conform with market changes, the ability to abandon a project prior to the completion of its life cycle, and the adaption capability of a new project. The component of control contains flexibility for continuous improvement, trouble control and rerouting, in work force capabilities, and work in process or Que backlog. The component of adaptation captures the factors of; changes in product mix, new item introduction, and market demand of product above producers' capacity.

Chatterjee [16] specifically focused on the issue of flexibility related to material handling, where the system agility is partially comprised by the ability to move different parts through various processes and machines. This premise is similar in concept to that offered by others where by manufacturing performance (flexibility) is a function of the degree of general purpose or multi task process and tooling (Gupta and Gupta, [23]; Pyoun and Choi, [47]).

Evans [21] offers a strategic perspective of manufacturing systems. This is best discussed using his framework for strategic flexibility, where four quadrants exist consisting of both offensive and defensive responses to current and future conditions (Figure 2).

TYPE OF FLEXIBILITY	CURRENT	FUTURE
DEFENSIVE	corrigibility	robustness
	resilience	hedging
OFFENSIVE	liquidity	agility
	elasticity	versatility

FIGURE 2: Strategic Manufacturing Flexibility Quadrants (Evans, [21])

In the defensive current quadrant firms perform damage control and institute corrective measures, reacting to an environmental event. For the quadrant of defensive future, firms establish contingencies, buffers, and back up methods. In the offensive current quadrant firms exploited the posture of leveraging and consolidation (The last area of offensive future contains the initiation of tactics, inflict damage to competing firms, create opportunities). The quadrant of offensive future is the action of altering the nature of the domain, striving for new methods of deployment and support (Evans, [21]; Heidegger, [26]).

From the above review of the reference discipline of operations management a consolidated suggested list of manufacturing parameters affected by flexibility can be established. Table 1 represents nine distinct parameters consolidated from the literature review of manufacturing.

TABLE 1: Suggested Referenced Parameters of Manufacturing Flexibility

Parameter	References
1) Current - Potential adoption of variations resulting from current environmental flux.	Chadra and Tombak, [14]; Evans, [21]; Gupta and Gupta, [23]; Jaikumar, [29]; Mitra, [45]; Sethi and Sethi, [50].
2) Future - Potential adoption of unknown variations resulting from future flux.	Chadra and Tombak, [14]; Evans, [21]; Gupta and Gupta, [23]; Jaikumar, [29]; Sethi and Sethi, [50].
3) A priori - Inherent existing system acceptance of variation.	Hyun and Ahn, [27].
4) Internal - Process changes resulting from internal forces.	Pyoun and Choi, [47]; Gupta and Buzacott, [22]; Hyun and Ahn, [27].
5) External - Process changes resulting from external forces.	Pyoun and Choi, [47]; Gupta and Buzacott, [22]; Hyun and Ahn, [27].
6) Tooling - Modified output within the confines of the process.	Chatterjee, [16]; Hyun and Ahn, [27]; Sethi and Sethi, [50].
7) Interchange - Rescheduling process components without disrupting outputs.	Sethi and Sethi, [50]; Son and Park, [52].
8) Investment - Incremental investment in system relevant to market demand.	Pyoun and Choi, [47]; Sethi and Sethi, [50].
9) Labor - Use of substitute labor.	Atkinson, Kec, and Stricker, [2].

IT COMPONENTS AS A SYSTEM

Given the above discussion of manufacturing flexibility we turn our attention to the IT environment. For the past twenty years there has been a continual increase in the complexity of IT applications found in the business world (As a point of reference IT is defined as both the technological and human sides of computer technology). Specifically, Turban, McLean, and Wetherbe [55] define IT as a system represented by a collection of components such as hardware, software, databases, networks, procedures, objectives, and people operating within the context of a set of cultural norms and values (e.g., managerial skills, corporate culture, and organizational structure).

The uses of the complete set of IT components have not always been recognized as important in the adoption of IT in organizations. This is supported by Benjamin, Rockart, and Wyman [6] suggesting that many of the original IT application initiatives were primarily the design of rank and file organizational members. These IT initiatives were often the result of applying available organizational IT technology, with minimal attention paid to broader issues of the non technological components of IT. This "bubble-up" method of identifying and applying IT solutions was frequently focused on the sub-optimization of internal processes such as accounting or inventory control, opposed to being focused on achieving an organizational wide goal (Cash and Konsynski, [13]; Kettinger, Grover, and Segars, [31]).

Chandler [15] did suggest that as IT applications evolved over time they would require the use of the broader set of IT components. Chandler's ascertains about changes in IT applications seems to have been correct as many organizations began utilizing all of the IT components, both the technological and human sides, as IT applications evolved from an internal focus to strategic focus for a competitive advantage (CA) (Ang and Pavri, [1]; Cash and Konsynski, [13]; Ives and Learmonth, [24]; McFarlan, [43]; Sethi and King, [49]; Venkatraman, [57]).

Boar [7] focused on the term of maneuverability to describe the ability of an IT infrastructure to be both proactive and reactive to changes in the business environment. Both Boar [7] and Broadbent, et al. [11] suggested that meneuverability attributes were closely associated to issues such as maintainability, modularity, scalability, adaptability, portability, openness of systems, autonomy data accessibility, inter-operability, and appliance connectivity.

Consider the implementation of Electronic Data Interchange (EDI), beyond offering a new method to reduce information cost and strength relationships, there existed a transitional state where the issue of flexibility was present (Van Over and Kavan, [56]). For the institution of e-mail systems, the transition state seems to be open ended as technology continues to modify the capability and application of the systems. These examples of change, as may be found in other IT applications, suggest the strategic use of the IT infrastructure contains a set of consistent factors (Kettinger, Grover, and Segars, [31]). These factors include:

1. The order in which the firm enters the change.
2. First movers to a technology or application to secure an advantage.
3. The response lag of competitors to enter the change, thus securing sustainability for the first mover.
4. Economies of scope and scale of change entrant.
5. Scope of geographic coverage of entrant.
6. Scope of product or services offered, and the skills required for each.
7. The organizational base strength in vision and implementation capabilities.
8. Proprietary control of systems.
9. Switching cost of new systems.
10. Buyer uncertainty of non first movers of change.
11. Availability of technical resources.
12. Quality of information resources.
13. Risk of preemptive strategies to the firm.

All of these factors have been associated with the sustainability of an IT derived competitive advantage. It is suggested that for each segment of each concept above, the organization must remain pliant and responsive to changes in their respective business environments.

When ITI is observed as a set of components it seems logical that these components can be viewed in the context of flexibility. In an attempt to better understand the flexibility of these ITI components a matrix is formed as shown in Table 2 below. This matrix is comprised of placing the three dimensions of slack, adaptability, and intensity on the horizontal plane, with the nine specific classifications on the horizontal plane.

TABLE 2: Item Matrix for Information Technology Infrastructure Flexibility

Classes	Slack	Adaptability	Intensity
Current	- The organizations ability to modify the ITI capacity as needed.	- To what extent does the ITI support optimization across differing architectures.	- To what degree are IT personnel involved in project selection.
Future	- The degree of IT backlog of strategic endeavors.	- To what extent have rules and standards designed to support future needs.	- To what degree does IT applications reduce the time to market for new products.
A priori	- How maneuverable the organization views the ITI. - The degree to which ITI is susceptible to modifications.	- The ITI supports vendor choices in network and protocol selection. - The degree to which application software can be transported across multiple platforms. - Restrictions of new applications based on the complexity of current applications.	- The degree to which relations, data and business rules are hard coded into applications. - The volume of change in technological generations.
Internal	- Time required to train new IT users. - To what degree the ITI supports the ability to vary work loads.	- To what degree is the ITI responsive to the firm's communications needs. - The degree of connectivity available across the organization	- The complexity level of the IT platform. - The degree that the ITI exhibits a sustainable level of complexity.
External	- The capacity of the IT infrastructure to cope with external business changes.	- To what degree does the ITI support vendor choices in network and protocol selection.	- The capacity of the ITI to assist in seizing existing business opportunities.
Tooling	- IT personnel have access to current technology.	- The IT infrastructure assists in eliminating excess personnel.	- The degree of depth of applications offered by the ITI.
Interchange	- The ITI creates buffers in operational processes.	- The degree that information is seamlessly shared across the organization.	- The degree to which the planning of ITI is associated to the function of localized departments.
Investment	- The degree that IT is a research area to be funded.	- The degree that the ITI is used as a tool for information based innovation. - The degree that the ITI is used in process re-engineering. - The degree of long term and consistent investment.	- The degree that the ITI is used as a source of competitive advantage.
Labor	- The degree that IT personnel are backlogged with all types projects.	- The degree that IT personnel are unencumbered in the performance of their respective jobs.	- The degree that IT personnel meet the ideal criteria.

CONCLUSIONS

Brancheau and Wetherbe [9] suggested that support exist for the alignment of the two concepts of competitive advantage and ITI flexibility, as they identified the increasing use of information for competitive advantage as one of the three major factors influencing the planning of corporate information structures. McKenney [44] and Keen [30] have also suggested that IT infrastructure can be viewed as a fundamental component in differentiating the competitive performance of firms.

The use of information technology as a component of corporate strategy has been popular for sometime (DeMeyer, [19]; Harrigan, [24]; Shank, Boyton, and Zmud, [51]). In some business settings the use of information management in strategy has become a necessity as the operating environments change with greater volume, shorter duration of effect, and increased complexity (Conner, [17]). This maybe due in part to the increased access to information channels by consumers, where an increase in the knowledge of a firm's rivals occurs resulting in the firm's need to pay a greater the amount of attention to those consumers need.

It is believed that the importance of a well defined IT infrastructure contributing to a firm's continual success cannot be over stated. In Brancheau, Janz, and Wetherbe [9] review of the key issues in Management Information Systems, they found that the predominant item of interest amongst survey participants was that of building a responsive IT infrastructure. These authors continued by stating that "more than any other, this issue (IT infrastructure) captures the thrust of contemporary IT management,..an IT infrastructure should support existing applications while remaining responsive to change, as this is the key to long-term enterprise productivity".

This issue of change is central in developing the argument for an effective IT infrastructure. Conner [17] suggests that the structure of change is centered around the concept of resiliency, encircled by the parameters of synergy, nature, process, roles, resistance, commitment, and culture. Conner continues in identifying the capacity to change as the ability to assimilate, the degree of control loss, and the cost of disruption. As a foundation Conner's [17] explanation is supported by the classical three phase model of change offered by Lewin [40], where change is a process from present state, to the transition state, to the final desired state.

LIMITATIONS

A reasonable amount of work has been done in defining ITI (Byrd and Turner, [12]; Duncan, [20]; Lewis and Byrd, [41]. But little investigation has been focused on the origins of ITI, and the relationship ITI has the foundations of flexibility. This paper offered a historical view of flexibility in the attempt to better understand the parameters and dimensions of the change required of a firm's IT infrastructure to achieve competitive advantages. Future research should look both to the past as well as the future to further our understanding of the systems we design and implement.

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