Technology Impact Grid: A Model for Strategic IT Planning for Competitive Advantage in Construction

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ABSTRACT

The dearth of information on successful cases of strategic use of information technology (IT) in the construction industry is the motivation for an investigation of the use and impact of IT in the construction industries of Spain, France and the United Kingdom. IT has yet to saturate the construction industry. Case studies of six firms in the three European countries which have the experience of using IT in a systematic manner revealed that firms can and do gain competitive advantage and improved business performance from using IT even though there are no explicit policies to gain advantage from IT. The Technology Impact Grid (TIG) was developed from the study. The grid uses two variables, degree of necessity and competitive advantage, to separate current IT into four groups: unwanted necessity, unnecessary investment, blessed potential and strategic treasure. It can be used both as a model for a firm's IT position evaluation and as a tool for planning IT acquisition to gain competitive advantage.

Key Words
competitive advantage; IT planning; IT position evaluation; technology impact grid; strategic planning

INTRODUCTION

IT is one of the new technologies having pervasive effect in every activity of the firm. It is affecting nearly all businesses and its presence is being felt everywhere in a rapidly increasing pattern heading where no one can competently predict. If every other area of human endeavour has improved as much as IT has, the world would be a better and cheaper place to live in today (Forrester, 1985).

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The notion that IT can be used as a business resource to gain competitive advantage is fairly established in different works. Most examples of such uses are from outside the construction industry. There is a dearth of such cases originating from the construction industry. Excepting few examples (Betts *et al,* 1991 for instance), published works in the field tend to be technical updates or general information.

Why does the construction industry seem to lag behind in the use of IT compared to other industries? What is the impact of IT use on construction firms? What management implications will the answers to these questions bring, and how should that affect firms in the industry in terms of strategy formulation? The study being reported in this paper attempts to provide answers to these questions.

THE STUDY

To address the questions raised above, the objectives of the study were stated as: (1) to formulate a working definition of IT based on literature on the subject; (2) to develop a model to evaluate the impacts of IT for competitive advantage (CA); (3) to examine the use of IT in the construction industry; (4) to determine, by the use of the model developed, the impacts of IT on the CA of firms in the construction industry; and (5) to draw out management implications for strategy formulation on the use of IT by construction firms.

The study focuses on the experiences of six (6) firms from the construction industries in three (3) European countries: Spain, the United Kingdom and France. All but one (1) of the firms were medium sized. The choice of medium sized firms was made to enable implications relevant to firms in developing countries to be drawn. Discussions with industry associations (Contractors Association of Barcelona, Spain; Paris Builders Federation, France; National Association of Construction Managers, France; and Building Employers Confederation, United Kingdom), institutes providing IT services to the construction industry (Catalan Institute of Technology for Construction, Spain; Services Society for Buildings, France; and Construction Industry Computing Association, United Kingdom), IT experts in academic institutions and published/unpublished surveys were used to supplement the information from the firms.

IN SEARCH OF A WORKING DEFINITION

Information technology is a rather new and unstructured field such that a standard definition of the term has not been established. It has been defined as 'the science of collecting, storing, processing, and transmitting information' (Forrester, 1985), 'information created by businesses and the technologies that process the information' (Porter and Millar, 1985), and as

'a combination of hardware and software used to collect, generate, store, process, analyse, disseminate and display information' Fan and Thornley (1986). IT can also be divided into two main categories: information processing, consisting of functions involved with the automated manipulation and distribution of information; and information transmission, the technology of transferring information among distantly located computers or between computers and remote peripherals.

There seems to be no generally accepted definition of IT. However, in many writings, information and IT are often interchanged. Furthermore, the majority of the writers on IT, include points such as hardware and software, the use of electronics, the convergence of computers and telecommunications, and the function of the technology for processing of data and information. As a working definition, IT can be defined as all electrically-operated equipment and facilities employed both to process data into information (i.e. collecting, sorting, analysing, storing, retrieving and disseminating) and to utilise processed information for any kind of decision making process, as well as the supporting software that enables the hardware to perform such functions and activities. From the definition, it is seen that the field of IT encompasses: computer technology, telecommunications and office automation.

Porter's Model and the Construction Industry

CA is the hinge that drives every business strategy. Porter's works on competitive strategy (Porter, 1980; and Porter, 1985, see also Betts and Ofori, 1992) form a helpful basis for the concepts used in rest of this work. He postulated that in any industry the five (5) basic forces that determine competitive structure are: the threat of new entrants; the threat of substitute products or services; the bargaining power of suppliers; the bargaining power of customers; and the rivalry among the existing competitors. Based on the analysis of industry structure a firm can choose a strategy to gain CA in the form of cost leadership or differentiation or focus.

According to Porter, a firm's activities in performing its business is a major source of CA. Porter identified five primary activities (inbound logistics, operations, outbound logistics, marketing and sales, and after-sale activities) and four (4) supporting activities (firm infrastructure, human resources management, technology deployment and procurement) as creating a margin for the firm in developing the concept of "value chain". To gain CA, a firm must carefully manage and exploit the linkages between activities in accordance with its strategy of cost leadership or differentiation. CA can also be created by optimising and coordinating the links to the outside or to a larger stream of activities Porter called the "value system". Since technology is used in both optimisation and coordination, it can greatly influence a firms strategy in gaining CA. The extent to which a particular

technology influences the elements of the industry in a firm's favour and causes the activities of the firm to be performed at a lower cost or in a more differentiated manner than its competitors is a measure of the firm's CA.

IT is one of the technologies that is reputed to provide CA when used strategically by firms (see Porter and Millar, 1985 Betts *et al*, 1991 and Betts, Undated). In the construction setting, IT can be used to create CA in many areas such as office automation, financial and administrative, procurement, computerised purchasing and telecommunication links to suppliers, materials handling and stock management, design, testing and a host of others. It may be used to lower costs or to create differentiation for a construction firm's products and services.

IT SITUATION IN THE EUROPEAN CONSTRUCTION MARKET

The construction market in the three (3) countries of Spain, France and the UK taken together was up to 225 billion ECUS (US$ 275 billion). Although this represents a huge volume of transactions, activities and flow of materials and information, the use of IT does not seem to have saturated the industry.

A survey of the top 900 firms (Peat Marwick McLintock and CICA, 1990) in the UK showed that 94% now have some computer equipment. IT expenditure by consultants average 1.5% of fee income, while contractors expenditure average 0.25% of turnover. This means that of the total industry turnover of 48 billion Pounds (US$ 86 billion) in 1990, the industry spent only 250 million Pounds (US$ 450 million) on IT. Even with that, industry authorities contend that computers are mainly used for administrative and financial tasks, such as word processing and accounting, and not in a strategic sense.

The situation in France is not so different. It is reported (Paris Federation of Builders and the Services Society of Building, Unpublished Report) that out of every 1000 computers sold in 1990, only 53 went to the construction industry. A survey of medium sized construction enterprises showed that computers are used for purposes similar to that in the UK. A study of the use of computers in Spain is not available.

The reasons for low level of computer application in construction are not unrelated to the size of firms. For instance, the U.K. construction industry has about 210,000 firms, about 195,000 of which employ fewer than 10 people.

The foregoing notwithstanding, major areas of IT applicgwions in the construction industry include: office administration and automation, estimating, computer aided drafting, project management, analysis and design, expert systems, robotics, and telecommunications. Except in the area of robotics, where there is as yet very little application, there is evidence of growing use of IT in the construction industry.

From the CICA study, and discussions with the construction organisations in the three countries, eight (8) major hindrances to IT use by construction firms were identified as:

The first is related to the fact that most big companies now act as coordinators and quality controllers rather than general purpose builders. The sub-contractors who undertake most of the construction work are small, unable to and unwilling to seriously consider IT use.

The second concerns the mobility of activities in construction. The tendency is that companies use local suppliers wherever projects are located and ties with previous project partners are easily lost; a situation which can be remedied with proper IT use.

The third is most applicable to Spain. The use of testing laboratories *in situ* for quality control especially in Spain eliminates the need for centralised company facilities.

The fourth is the problem of lack of standardisation. Unlike most other industries, construction processes and product still remain largely unstandardised thus inhibiting the use of IT as proximity to suppliers is crucial and many components are fabricated on site. If orders could be specified using standardised codes, suppliers can be from anywhere and links can be established permanently which would favour the use of IT.

The fifth problem is that still many in the construction industry consider IT not as a *sine qua non* for the survival of a construction company. There are many who believe IT can improve efficiency but would not give a major competitive advantage.

The sixth derives from fluctuation in construction activities. It is a known fact that the cycles in the economy are always accentuated in the construction industry. It is not clear whether investment in IT should be made during a recession or in periods of boom. As such, a strong and coordinated impetus in the whole industry to invest in IT is lacking.

The seventh problem is worker related. Poor level of education of site workers make it difficult for them to be trained in the use of IT. Also, project heads do not have sufficient IT culture to accept the potential of IT and to use them.

The eighth and final problem is that the general attitude of the people who compose the top management of the companies in the construction industry. Heads of companies often view investment in IT as dispensable expenditure and are reluctant to introduce technological changes that will affect their management styles.

Table 1: IT Components Possessed by Companies Surveyed

IT components possessed	DGC	ALC	PWC	BGC	RGC	STC
Mainframe	*			*		
Mini-computer		*		*		
Workstations		*		*		
PCs	*	*	*	*	*	*
LAN		*		*		*
UNIX network					*	
Digitizers		*				
Fascimile	*		*	*	*	*
Cellular phones	*	*	*	*	*	*
Teleconferencing	*					
Dial up modems			*	*		
Scorpio communication systems				*		
PSION (surveying)			*			
"Intelligent" building systems				*		
Word processing	*		*	*	*	*
Accounting	*		*		*	*
Billing					*	*
Payroll	*				*	*
Database		*	*	*	*	
Estimating	*			*	*	*
Design (piling)	*					
CAD		*	*	*	*	
Project management	*	*	*	*	*	*
GIS		*				
Integrated MIS				*		
Engineering applications (Structural analysis and design)		*		*	*	

IT Use in the Companies Surveyed

The survey of eight firms was conducted through site visitation and semi-structured interview. Table 1 shows the major IT components possessed by the firms surveyed. The highlights of IT use in the companies are presented below.

DGC: This British general contracting firm, quoted on the stock exchange, has completed over 3000 contracts and has annual turnover in the range 60 to 70 million pounds. Its major specialty is in design and construct projects.

Teleconferencing has eliminated the need for professionals (Contracts manager, estimators, site staff, and purchasers) to meet physically in meeting for contracts management resulting in reduction in costs and faster decision making. In addition, word processing applications has vastly increased the ability of staff to cope with mailings and enquiries. The company currently uses four (4) persons to produce about 900 letters a week and is in the

processes of integrating IT components that will vastly increase its volume of sales and shorten decision making time.

ALC: The company is a large British engineering consultancy firm engaged in a broad range of construction work and providing a broad range of services related to construction: finance, feasibility studies, planning, design, quality assurance, *etc*.

Reckoning that it possesses excess capabilities in IT, this company has created a subsidiary that offers services to the company and other organisations. Through the subsidiary company, applications developed by ALC are offered to other clients. It also has established a sophisticated GIS that creates a barrier to entry for would-be competitors.

PWC is a large UK based building surveying and architectural practice having more than 120 professional staff. It also has joint ventures and subsidiary firms.

The company's notable IT component is the PSION hand-held system used for capturing survey data on site. Information collected on site using the system is easily downloaded to a PC in the office. Survey time is thus reduced by 30-50% resulting in substantial cost savings to the company.

BGC is a very large French company engaged in general construction, property development electrical contracting and maritime works. It currently employs about 80,000 employees.

The company has developed and is using many IT components of which "intelligent building system" gives it a competitive advantage over its rivals. The company has set up a subsidiary to market its system and to provide a differentiated product which strengthens the company's competitive position in industry.

RGC is Spanish firm employing about 125 professionals with a turnover of about US$ 20 million. The company has a networking system integrating its three operating centres: head office, technical office and plant for wastes. Through the network, the company is able to integrate what would otherwise have been stand alone packages. Networking makes the IT components more efficient and productive and thereby, lowers costs.

STC is a medium sized family construction business (turnover US$ 30 - 40 million) employing 200 people of whom about 100 are permanent employees. The company business is focussed on industrial plants (60%), housing (30%) and general works (10%).

The company gains a competitive advantage through its LAN. The network connects the company to its major client, a real estate company, and thus reduce costs substantially through efficient and quick communications which facilitates effective and timely decision making.

THE TECHNOLOGY IMPACT GRID

A Needed Dimension

CA is a motivation for a firm to introduce IT in the management and operations of its business. A pertinent question at this point is, "Just how does a construction firm decide on whether or not a piece of IT is able to create CA?" For a tool like IT where its proliferation causes competing firms to acquire what everybody else has, just a simple look at how it gives CA is not enough to determine the essentiality and impact of an IT component. IT has to be divided into components here to see an overall view of IT in its widest range, and not just to isolate few successful cases and take them as representatives of IT's performance. A lot of investigators have failed by adopting the latter approach causing people to take the potential of IT 'hook, line and sinker'. Reports on the successful application of IT in some special cases should not be a reason sufficient to adopt IT.

Although the attractiveness of an IT component depends on the degree of CA it gives a firm, components which give low CA cannot be simply ignored. From the management point of view a new dimension is needed *ie,* the Degree of Necessity (DN) of the IT component in the daily conduct of the business. Low DN means that the company's operations will not be delayed, hindered or affected in a significant manner even if the particular IT component is not used; and high DN means that the IT component is vital for the normal operation of the company and without it, the normal activities of the company will be delayed, hindered or affected significantly. This dimension is needed to give a balanced picture of the IT component for it shows how crucial the component is to the normal operation of the firm. The two dimensions - CA and DN - taken together provide a powerful framework to evaluate the impact of IT on the firm. It allows distinction between essential and non-essential IT components. For a particular firm, an IT component may give low CA but if without it the firm would not survive, then it becomes an essential element of the company. The suggested model 'Technology Impact Grid (TIG)', for evaluating IT components is shown in Figure 1. The different sections of the TIG require explanation.

Unnecessary Investment: "Inappropriate" Technologies

IT components which give low CA and at the same time have low DN fall in this section of the grid. Components belonging to this category could be those that are entering obsolescence because of newer and better substitutes; or they could be equipment that have once been a fad but do not prove to give CA, neither are they better than the manual or older technology used by the company to merit a complete and permanent switch to their use; or they could be software or systems developed or obtained mainly for convenience.

Many companies possess such IT components without being aware that they are investing in an "inappropriate" technology. Once the company realises this, it can respond to correct or improve the situation. The first option if nothing else is affected is to dispose of the technology. However, there are cases where the technology is connected to the morale of the workers, especially those which give convenience in discharging their duties. In such cases management should seek a more strategic use of such components by considering the possibility of integrating certain software or finding better uses of the components. Management could consider not investing on further peripherals to the components and limiting expenditure of time and attention in optimising or improving the system.

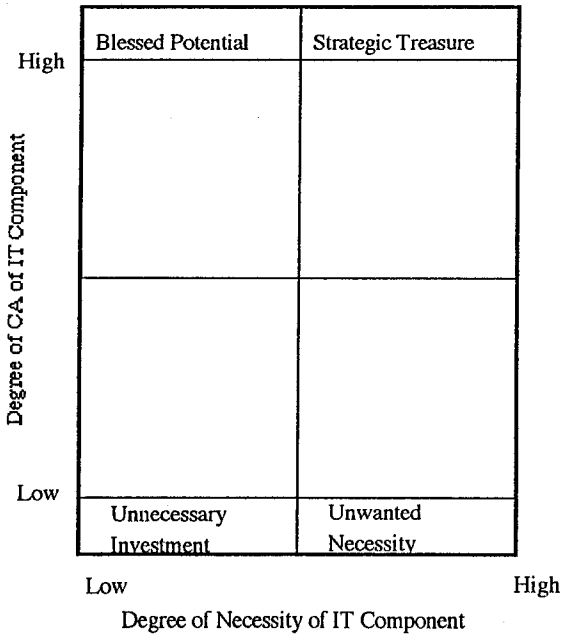

Figure 1. The Technology Impact Grid

Blessed Potential: "Emergent" Technologies

These IT components provide high CA but the company and its employees are not yet hooked into their use. "Emergent" technologies are equipment or software that are proprietary or new in the market. Those that are proprietary are developed in-house to enhance the competitiveness of the company, while those that are new in the market are bought by some of the most daring and IT driven company executives who have recognised their

benefits.

This category of IT components present great potential for the company, but since they are not critical for its normal operation there is a risk that the employees will ignore them and therefore not realise the advantages of using them. It is most likely that for every such component there is a traditional way of doing things and without an explicit company policy to use the technology, the more conservative employees will stick to using what is familiar. The challenge for the management is to harness the potential of these technologies and reap first-mover opportunities and advantages.

Strategic Treasure: "Key" Technologies

This section of the grid offers the most strategic implication for management. IT components in this section are considered to be "key" technologies because they afford high degree of CA and are also needed for the company to perform its business activities. They may have been emergent technologies which have established and fully evolved into applications necessary for the operations of the business.

IT components in this category have the most strategic significance because failure to manage the components properly will not only result in trouble for the company's operations but also erode the company's competitiveness. Therefore, attention should be given to the maintenance of the components, improving the technologies or systems by innovation, and it is components in this category that companies are most reluctant to invest in. Firstly it would mean a deliberate and complete switch from traditional methods; and secondly, it would mean a dependence on a particular component. Due to this inertia though, those able to boldly pursue the investment could establish a lead while competitors have not adopted the same technologies.

Unwanted Necessity: "Basic" Technologies

When key technologies become so commonplace that virtually everyone has them, they cease to give CA. The technologies then become "basic" to the industry. Unfortunately, the company's dependence on the technology for its operations remains. Although the IT components in this category are no longer attractive strategically, they are "must haves" for the survival of the company. Management concern for managing this category of IT components should focus on cost savings in their use through efficiency, better performance and saving in material inputs.

Model Use and Weakness

The model is intended as a guide for managers to assess the strategic impacts of IT components. The aim is to enable effective deployment of

organisational resources by facilitating proper response to the different IT applications. Its primary strength lies in its emphases on both factors that are external to the company such as CA dimension and a factor that is internal to the company which is operational necessity. Both dimensions are important. Knowing the CA that can be gained from IT components is valuable, but without the 'necessity' dimension managers will lack a solid idea on how to manage or what to do next with the technology especially with the presence of threats of imitation and close following by competitors. Another strength of the model is its foundation on a model (Porter's) that is popular and accepted by top management of corporations. The model also provides a means for evaluating a wide variety of IT applications. Finally, it can be used for identifying IT needs on the basis of the company's existing operations and future plans.

The main weakness of the model is that it is a *post-facto* model which can best be used for the current applications a firm has. To use it for identifying opportunities for strategic use of IT would require gathering relevant information from other firms. A model of this nature should not be taken as a tool of IT strategy formulation, nor does it show how to use IT to gain CA. What the model does is to help in evaluating the performance of the company's IT strategy by showing its impact and guiding management on how to properly respond.

Measuring the DN and CA

Time limitations and lack of access to needed data precludes quantitative measures of CA and DN in the companies surveyed. A practical approach is to make intuitive judgment on how IT components affect the different aspects of CA. Since the extent to which a technology influences the elements of the industry structure in a firm's favour and causes its activities to be performed at lower costs or in a more differentiated manner is a good measure of a firm's CA, an intuitive measurement of CA of each IT component can be devised. A rating of 1 (representing no effect) to 5 (very high effect) was adopted. For example, the concept of "drivers for cost and uniqueness" is valuable in evaluating the factors of "lowering cost" and "enhancing differentiation" respectively. The different aspects of CA given here are assumed to be mutually exclusive, i.e. the effect of an IT component on each aspect is distinct' though this may not be true in reality. It is therefore possible for a component to have very high effect on say, lowering costs but have absolutely no effect on other aspects. Thus to obtain the final quantitative value of the degree of CA of an IT component it is only necessary to consider the aspect of CA which the component affects most i.e. the aspect which has the highest rating.

For the DN, respondents were asked to rate, on a scale of 1 (for not

necessary at all) to 5 (extremely necessary), the degree to which a particular IT component is necessary for the daily operations of business.

Aggregating the components and plotting together in the model provide a wider and integrated view of the impacts of IT components. It also dampens the biases of individual companies. The following steps were adopted in the analysis.

Step 1: For each IT component, determine which aspect of CA has the highest rating i.e. the aspect of CA the technology affects most. Do the same to each IT component of the rest of the firms.

Step 2: For each IT component, compute the composite value of the CA using the formula:

$$\textit{Degree of CA of IT Component} = \frac{1}{n}\sum_{i=1}^{n} (CA)_i \qquad (1)$$

where: CA = the value of the aspects which have the highest rating in each firm

n = no. of firms that have the IT component

Step 3: Repeat step 2 for DN by substituting DN for CA in Equation 1.

Step 4: Plot the location of the IT component in the model.

Evaluating the IT Components of the Six (6) Firms Using the TIG

A plot of the calculations of CA and DN is shown in Figure 2. It gives a clear picture of the impacts of both the individual IT components and IT as a whole in the firms surveyed. The grid shows which components are important and can be used in deciding what to do with IT components. For instance components in the "unnecessary investments" section of the grid are stand-alone items which can be integrated into MIS which is shown in the model to give higher CA.

A bulk of the components are in the unrealised potentials section. The best strategy is for management to promote the use of these components. BGC and DGC have been doing this with the Scorpio communications systems and teleconferencing respectively. BGC managers reported that their 5 year goal is to ensure that "every company in the Group, with no exception, is to be linked to the head office and internationally."

The IT components in the "strategic treasure" section are highly used by the firm and are also giving high CA to the firms. The firms possessing these components could maintain their competitiveness through upgrading such as customising them closer to the specific needs of the firm or enhancing the features. BGC company has customised its estimating applications to allow it to display three currencies in keeping with the international nature of the firm. The CAD and project management applications at the border of two

sections are becoming key technologies as employees become more versed in their use and customers increase in sophistication. Word processors (and to some extent FAX machines) which should be "basic" technologies are still giving CA since some firms in the construction industry are not using them yet.

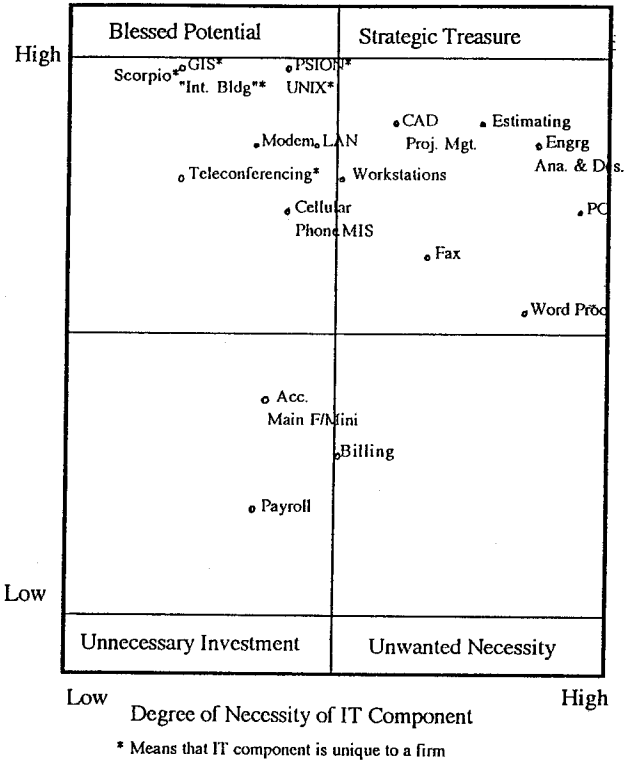

Figure 2. The Impact of IT in the Construction Industry As Plotted in the Technology Impact Grid Model

Regarding the overall impact of IT, it can be induced from the plotted model that IT has not yet fully permeated the construction industry. A majority of the IT components are still considered "emergent" and almost none has regressed into "basic" technologies.

A word of caution are necessary for would-be users of the model. To use TIG correctly, IT components need to be grouped into subheadings, say, infrastructure systems (networks, FAX, *etc*,) and core business applications (accounts, estimating, *etc*,) before useful comparisons can be made.

CONCLUSIONS AND IMPLICATIONS FOR STRATEGIC IT PLANNING FOR CA

The major conclusion from this study is that IT has not yet realised its potentials in the construction industry. Based on the experience of the six European companies studied, the following managerial implications are useful in formulating an IT strategy.

Managers should analyse the uses of their existing IT components and the impacts of these components on both CA and DN to the firm's operations, as a basis to formulate policies for managing IT components in terms of resource allocation, investment decisions, more strategic uses, or upgrading schemes. The Technology Impact Grid allows managers to perform the exercise.

Managers should not treat all IT components as the same, but they should manage the components depending on its use and impact on the firm. The model presented, though still being developed, could be used for IT planning based on current operations.

IT could be used by firms to influence construction industry structure in their favour by raising barriers to entry, creating new and transforming old products and services, and widening competitive scope. IT supports a firm's competitive strategy of either cost leadership or differentiation by performing cost savings in its activities (such as shortening time, eliminating repetitive tasks, exploiting communication linkages, *etc*,) and enhancing quality of products and services respectively. Surplus IT capability and skills as well as less critical proprietary applications could be sold in the market as a new product or service. This could be a basis of creating new business.

Since IT in construction is in the introduction stage, firms could exploit first-mover opportunities and establish leadership by investing in applications that allow for strategic uses before others catch up.

The fact that the construction industry is seen to be lagging behind in the use of IT compared to other industries does not mean that the firms in the industry see less benefits in the use of IT. Rather, the industry has unique characteristics that inhibit the rapid growth of IT.

Although the firms in the construction industry in general are slow in adapting to the strategic use of IT, and many managers are still reluctant to tread the course towards the use of IT, those who have made an explicit decision to use IT in a systematic way, unambiguously acknowledge that IT has given them CA and has improved business performance.

For firms which do not possess IT culture, managers in charge of IT should "prove" the benefits by actual demonstrations through test applications to convince top executives and employees of its usefulness. In order to create an environment in a firm conducive to successful implementation of IT, training of people with the aim of affecting a culture change should be done.

IT should not be viewed as an end in itself, but it should be treated as a tool to support strategic objectives of a firm, improve decision-making, enhance image, improve competitiveness and provide vital linkages.

The firms in the industry should support an effort towards standardisation in construction. This is seen to promote more effective use of IT.

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