

A reflexive capability model for sustainable e-business environments in construction supply chains

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Abstract

Despite the increasing significance of e-business worldwide and significant construction market leaders developing innovative e-business applications, the widespread uptake in the Australian construction industry is lagging. The industry appears to be not taking advantage of potential e-business efficiencies and benefits. This is problematic because of the critical role that the construction industry plays in the overall Australian economy and the flow on effects it has on other sectors and the future environment the market leaders wish to take the industry as a whole. There has been much literature related to e-business adoption focusing on drivers and barriers to adoption. However, there has not been an investigation that has applied fundamental supply chain theory concepts. The cornerstone of supply chain theory is the modeling of the flow of cash, products and information. This work differs in its attempt to integrate the three components rather than thinking about adopting drivers or barriers reliant upon one or the other. An industry wide long term sustainable e-business model relies upon a deeper understanding of the underlying structural and behavioural characteristics of the manner in which firms behave within their individual sectoral supply chains. This industry model for e-business sustainability requires a consideration of both the economic and social practices of firms. In this paper a reflexive capability model for the individual firms in relation to e-business is developed which relies upon merging economic and social practices through an industrial organization economic theoretical lens and social science theories of communication. The flow of cash and products is reinterpreted through the industrial organization economic theory. The understanding of competition and collaboration and the flow of information in the supply chain is considered through diffusion theory and heterophilic and homophilic modes of communication. The reflexive capability model proposed is a framework that describes the continuum of e-business adoption by individual firms within their competitive and collaborative networks which is currently being tested as part of a nationally funded study. The model is proposed for the construction supply chain to enable awareness, engagement and realization of e-business technology and achieve long term construction e-business sustainability.

Introduction

Australian statistics (ABS, 2004) comparing construction to all other industries indicates that the construction industry ranks last on all four key performance indicators in relation to e-business uptake. This is problematic because the industry is not taking advantage of the various anticipated

and real benefits and efficiencies that e-business has to offer. Specifically it is problematic because of three reasons:

- the critical role the construction industry plays in the overall economy in relation to employment and GDP and its linkages to other sectors and the flow on effects;
- its linkages to other sectors in terms of information flow and contractual relationships; and
- The significant investment of resources in information technology by government and leading players in the construction industry as they develop innovative e-business industry solutions (London, 2004).

It has been well discussed in the literature for more than a decade that a key to productivity improvements for the construction industry relies upon more efficient and effective information management (Davidson, C. 2004, McGeorge, Chen and London 1994; McGeorge and Palmer, 1997). This has more recently been translated into electronic management of information in the form of web-based project management systems to manage consultant document coordination during the design phase. Coupled with this is the high level of contracts which occur on a project which again makes the construction industry ideally suited for e-business technology. Therefore the main claims of the benefits of e-business technology are that it will provide commercial efficiencies through more effective design and construction information management and procurement and contract management. However after the initial adoption by innovative firms, e-business has not dispersed throughout the industry.

It is useful to consider three key characteristics of the construction industry as this affects research into how this industry adopts e-business. Firstly, it is characterised by numerous small to medium enterprises (SMEs) whereby approximately 93% of the industry is composed of SMEs (ABS, 2004). It is critical to examine the barriers to technology adoption by this particular group since this impedes effective industry-wide diffusion of e-business technology. However the adoption by larger scale enterprises (LSEs) is a critical factor that may impact upon diffusion as well, particularly for the civil sector. It is important to note that different sectors of the property and construction industry, that is, building, civil and residential have different market structures and therefore may result in different factors affecting adoption by that sector. The discussion on market structures is important and is taken up further in the section on supply chain theory.

Secondly, it is a project-based industry and therefore contractual relationships are constantly forming and reforming as firms respond to projects. The temporary organisation and the fragmented nature of the industry have been well discussed in the past. It is a myth that the industry is largely a sea of atomised, non-cohesive, fragmented SMEs who are non strategic actors (London, 2005) – there are indeed long term and cohesive relationships in the industry and there are substantially well coordinated and strong networks (London, 2005). SMEs do act strategically – they tend to identify their risk and act as strategically as the market structure and competition environment allows them. The temporary nature of contractual relationships does impact upon e-business adoption in terms of risk management; that is, firms do not want to embark upon adopting new technology if the majority of their suppliers and/or clients/customers are not involved in the same technology on the next project. Therefore the competitive nature of the markets and the level of integration of existing business processes between actors along the

supply chain is an important consideration.

Finally, currently the aim for e-business adoption of larger clients and contractors in Australia primarily revolves around construction website portals. Construction portals typically provide three main functions related to construction projects including: project web-based documentation management; on-line tendering; and on-line purchasing and invoicing - all services which are located within the one website.

Many elements of a technical solution have been solved and are available; therefore the research must address the significant changes in business practices and consider strategies that will address social, cultural and economic issues at a supply chain and organisational level.

The aim of this paper is to develop a theoretical model for e-business sustainability at a supply chain level. The argument for supply chain level adoption is discussed in detail later. The model is derived from considerations of the barriers and drivers of adoption at the organisational level related to economic and social structural and behavioural environment and the capacity and degree which the individual firm can and does engage in e-business. The reflexive capability model for e-business sustainability relies upon defining economic environment

The paper is outlined as such:

- Identification of barriers and drivers for e-business identified in the literature and an explanation of barriers and drivers in relation to supply chain theory and innovation diffusion theory
- Discussion of supply chain theoretical framework focussed on industrial organisation
- Critique of diffusion theory and identification of key problems with diffusion theory
- Description of the elements of innovation and the modes of communication
- Description of reflexive capability model
- Outline of next stage of research

Barriers and Drivers for E-business Adoption

There has been a great deal of literature related to e-business adoption and much of it has focussed on these two key concepts: barriers and drivers. The barriers and drivers to e-business adoption, which have been identified in the literature, will now be discussed and critiqued.

General speculation on the reasons for slow adoption of innovative technology, such as those afforded by Information and Communication Technology (ICT), has occurred in other industries and has been attributed to such factors as:

- lack of awareness of what e-business is and what it involves and further to this a lack of awareness or reluctance to see potential business benefits (Ingirige and Aouad, 2002; NOEI, 2001; Parish et al, 2002);

- informed resistance to innovation based on values and attitudes;
- the lack of security and the perception of an insecure environment; the need for a regulatory and legal framework; lack of systems; (Bennett, Cobbold and Phillips, 2003);
- market incentive, pressures, rewards and uncertainty regarding the financial returns from investments in various resources versus economic benefits (Tetteh, 2001; Veeramani et al, 2002).

A review of these factors identified as potential barriers to the adoption of ICT in various industries reinforces the notion that further research must begin to take into account social and cultural issues at supply chain, organisation and individual level. This is particularly evident when it is acknowledged that while the capabilities of the technology itself are rarely in question, it is the perception of the technology, and uncertainty regarding benefits and advantages of adoption that are the underlying reasons behind the above barriers. Thus adoption (or lack thereof) is a human issue, and relates primarily to the shared social and cultural meanings that inform both the individual and organisational interpretations of the economic value and economic risk of ICT. The importance of explicitly recognising perception and interpretation of value as the underlying barriers to e-business adoption is that these social and cultural meanings are dynamic and flexible. Preconceptions can be challenged, perceptions altered, values and attitudes toward innovation adjusted, uncertainties reassured and, eventually, different decisions can be made (Frank, Zhao and Borman, 2004). In this respect communication emerges as a central concept in understanding the barriers to adoption and the development of any strategies designed to overcome those barriers.

In addition to a general outline of barriers to adoption of e-business, the literature has revealed the following factors which have been suggested to assist in the process of e-business adoption including;

- rewards, incentives and initiatives by governments including seeding programs, investment incentives and tax rebates etc (NOIE 2001),
- managerial characteristics or philosophy of the firms (Gray et al, 2002),
- culture of the firm (Elliman and Orange, 2000; Gray and Lawless, 2000),
- SMEs characteristics related to flexible specialisation (de Berranger and Meldrum, 2000; Malone, 1985; Montazemi, 1998; Storey and Cressy, 1995). It is the flexibility of SMEs that can make adoption of ICTs easier, compared to larger more bureaucratic and inflexible firms (de Berranger and Meldrum, 2000) and some commentators claim that SMEs could be expected to adopt technology faster than large firms,
- production related factors assisting e-business adoption; for example e-business technologies have the potential to transfer complex design information accurately (Elliman and Orange, 2000), thereby eliminating data transfer error (NOIE, 2001), as well as minimising delays as information is conveyed along the supply chain,
- reduction in transaction costs; small vendors and suppliers can bid on jobs using standardised forms on the site making bidding on jobs relatively inexpensive; costs in

transferring information during the tender process is reduced. The website is also beneficial to large manufacturers as it creates an electronic auction market enabling firms to receive a wide range of competitive quotations from vendors (Wenninger, 1999).

The relative influence exerted by these factors can be grouped according to their position in what Roger's (1995) describes as the innovation-decision process. That is, the process by which an individual or group moves from first knowledge of an innovation, to forming an attitude towards the innovation, to making a decision and actually moving ahead to implementation. In essence, the first four drivers above exert their influence either prior to the decision to adopt, or in the implementation process, whilst the final two exert their influence following the implementation of the innovation. The first driver identified above influences the process of forming an attitude towards the innovation and the subsequent decision of whether or not to adopt. Government based incentives are aimed at improving the attractiveness of adoption to individuals and firms by offering financial support and thus addressing a key issue of financial risk. That government intervention is aimed at the phase of development of an attitude (perception) toward the potential benefits of e-business is significant in identifying this phase as crucial to the overall process.

The second and third drivers above explicitly highlight the importance of organisational culture and the social meanings and values that influence decision making in the form of management practice or managerial philosophy. The managerial philosophy also reflects the position that managers take in relation to the perceived risk vs value in relation to e-business contributing to a firm's profitability. The decision to engage in e-business relies upon awareness of benefits, acceptance of advantages vs disadvantages and capacity to then move the firm in that direction. Hand in hand with social and cultural values is the economic space that the firm is located within; if managers do not have an economic imperative to make change then there is little incentive to make changes to the business practices of the firm. Economic imperatives can include; opportunity for new markets and/or new clients, improved internal and external efficiencies, existing clients and/or suppliers demanding change and current competitors adopting new approaches to e-business.

The fourth driver describes the supposed advantages of SME organisational characteristics as related to flexible specialisation. In relation to the innovation decision process, this supposed driver exerts its influence in the implementation phase, in that the smaller size and more flexible firm's characteristics make organisational restructuring that follows the adoption of e-business less costly and time consuming. Given that 93% of construction firms are SMEs, their organisational characteristics are a factor that should assist them in adopting e-business technologies. Given also that the Australian construction industry displays significantly lower levels of e-business adoption than other industries, it would seem that advantages bestowed by organisational characteristics alone are insufficient to assure the positive interpretation of the values of adopting e-business technologies and practices.

The final two drivers listed above are both related to organisational and financial benefits accrued by adoption of e-business. These aspects can be drivers in terms of the confirmation of the decision which leads to further adoption of e-business innovations. They can also act as an influence, by way of a positive example and tangible experience of the advantages, on other firms considering adoption and currently in the phase of the formation of attitudes toward the innovation. For this positive experience to be useful as a driver for another firm, again the theme of communication is raised. The theme of communication and its role in e-business uptake is discussed in more detail in the section on Modes of Communication.

In the discussion of the barriers and drivers to e-business adoption identified in the literature the point has been to acknowledge that e-business adoption is a complex and multi-phase process that is heavily reliant on the provision of information and communication between individuals and groups. In doing so it is clear that future research into e-business adoption in the construction industry needs to examine the process in a cultural and social context that takes into account the complexities of the wider social system in which individuals and firms are embedded as well as the economic context within which these communications take place and are contextualised.

Although this field is quite extensive in terms of barriers and drivers related to e-business adoption and provides a useful starting point from which to conduct future research into the specifics of the construction industry's adoption of e-business, significantly, past research has failed to take into account in an integrated fashion some of the key structural elements of the industry. These include:

- attributes of SMEs flexible specialisation and clustering;
- the role of different supply chains and competitive behaviour in a project based industry
- the integration of business processes along the chain; particularly that offered by construction portals; a significant new virtual cultural, economic and social “space” that key client government organisations and construction market leaders have taken up with enthusiasm; and to their dismay have been surprised at the general lack of “followers”; thus resulting in the nationally funded research project of which the first stage is reported in this paper.

Supply Chain theory

A brief consideration of the supply chain concept serves as a useful theoretical framework for the development of the reflexive capability model which is described in detail in the section: Reflexive Capability Model for E-business Sustainability. There are numerous interpretations of what the supply chain is and at what level a supply chain is considered (London 2001). For the purposes of this paper an industrial organisation economics perspective has been developed.

The supply chain is the firms that are involved through upstream and downstream contractual relationships who deliver a commodity (product and/or service) related to the core business of a construction project. The supply chain once formed creates a flow of commodities, cash and information. The creation of the supply chain is impacted by the location of the individual firm within its competitive market; which has unique economic structural and behavioural characteristics. The upstream and downstream linkages are affected by the nature of these markets and then the countervailing power which occurs between subsequent markets at adjacent levels in the chain (London, 2005). Firm behaviour in relation to the adoption of innovative technology (in this instance, e-business technology) relies upon; the individual firms economic pressures as a result of market competition (the behaviour of their immediate competitors), the upstream and downstream linkages that they typically find themselves located within and then the social practices of their upstream and downstream suppliers and/or clients.

“Interest in the supply chain management concept by the construction research community arose

from the successful implementation by manufacturing sectors to resolve firm performance problems. Construction industry policymakers have also appropriated the concept. Researchers tend to develop normative models to improve industry performance through supply chain integration. Such models are based upon the assumption of a homogenous industry, but one which is fragmented and composed of numerous small to medium sized enterprises. Policymakers are seeking positive economic models, however, policies are not based upon an explicit detailed understanding of the nature of the industry nor an explicit model of firm and industry performance. The positive economic model accepts that the industry is specialised and heterogenous with varied structural and behavioural characteristics across individual markets. The greatest difficulty with supply chain management in terms of construction research theory and practical application is that currently too little is known about these characteristics and how to describe them. Procurement modelling across the supply chain is fundamental to describing the underlying structure and behaviour of the industry. The industrial organisation economics theory can make contributions to our understanding of the way in which the industry behaves” (London, 2005).

The market structure- firm conduct- industry performance inter relationships framework assists in our understanding of the way in which different commodity supply chains (façade, aluminium windows, mechanical services, glazing, pre-cast concrete etc) diffuse adoption of e-business. The reason why procurement modelling is important to consider in this study is that procurement decision making is a key activity that threads its way through the industry. Decisions in relation to the firms we choose to work with and why we choose to work with those firms can dramatically impact the awareness, attitudes and decision process involved in uptake and implementation of e-business.

There has not been an investigation that has considered the organisational behaviour of participants within various supply chain networks and the role that this plays on e-business adoption. It is speculated that the new technology is diffused through various clusters because of their business linkages and interdependence. Past research (Gray and Lawless, 2002; Elliman and Orange, 2000) has been reductionist in its approach and assumed adoption is dependent upon individual variables and that adoption relates to an individual firm’s choice as an entity that does not operate within a social system.

For e-business to be successful, diffusion must happen from business to business within the supply chain as well as within the individual businesses. The economic and social system for the supply chain in the construction industry is related to the following key players: upstream clients, downstream suppliers and market competitors. Therefore diffusion must take place between firms and just as significantly within the firms for e-business to be successful. The common themes of Risk, Trust and Social Capital underlie the concept of diffusion within and between businesses developed in this paper. Diffusion of innovations can filter and spread within the following social and business ‘spaces’:

- Up and down to all operations of management within a firm
- Up and down businesses through the supply chain
- Across a smaller group of firms within a market; who are consistently procured within the similar upstream clients and downstream suppliers network; that is competitors within a

submarket

Ultimately the success of the diffusion of e-business is reliant upon the firms' economic and social "space" or environment and then the capacity to achieve change. Although it is important to be aware of the structural drivers and barriers to e-business, our research focuses on the importance of diffusion within and between businesses and the interdependencies between upstream and downstream markets along the supply chain for the adoption of e-business. Rather than taking the approach that a firm either adopts or does not adopt we are suggesting that adoption and ultimate dispersion across the industry is based upon firms being along a continuum of "reflexivity" relying upon e-business awareness, responsiveness and adaptability attributes. The reflexive capability model focuses on the importance of communication, social networks and social, cultural and economic capital for increased awareness and diffusion of e-business within supply chains. It is based upon the premise that the behaviour and attitudes of firms towards technological innovations can have significant influence on the acceptance and ultimately the dispersion of e-business by other firms within the supply chain. This model of diffusion suggests that people change perceptions about the value of an innovation through communication and it is these perceptions that then drive implementation. The next section describes the diffusion process of how technological innovations are communicated, adopted or rejected and finally implemented and diffused.

Diffusion Theory

Rogers (1962; 1995) has considered the diffusion of new technology in his text *Diffusion of Innovations*. Whilst not referring specifically to the diffusion of e-business as innovation, Roger's work does provide an initial framework through which examination of the diffusion of e-business through supply chains can be examined. Rogers defines the diffusion of innovations as the process by which knowledge of an innovation is transmitted through communication channels, over time, among the members of a social system. Therefore, the four key elements comprising Roger's diffusion theory are defined as:

- The innovation: an idea, practice or object that's perceived as new;
- Communication channel: can be mass media and/or interpersonal networks and is the means by which messages about the innovation gets from one individual to another;
- Time: comprising a) the innovation-decision process, b) relative time with which an innovation is adopted by an individual or group - an innovation's rate of adoption.
- The social system: a set of interrelated units that are engaged in joint problem solving to accomplish a goal.

Within this framework diffusion is largely measured through the degree of adoption within a social system. Adopters are categorised into innovators, early adopters, early majority, late majority and laggards. These adopter categorisations are differentiated primarily in relation to diffusion as a temporal process – diffusion happens in time, whilst the other key elements of innovation, communication channels and social system exert variable influence upon the temporal diffusion process depending on their specific qualities. For example, communication channels vary in importance according to the type of adopter; mass media and expert knowledge has more influence on innovators, whereas personal networks are more important for late-adopters. Which is to say, the type of communication channel has influenced the *rate* of adoption, for the difference between an innovator and a late-adopter, according to Roger's is simply the relative time in which the diffusion process has occurred. The key processes in Roger's diffusion theory

are, thus, the innovation-decision process and the rate of adoption - comprising multiple phases, and influenced by various factors. As noted earlier in relation to a discussion of the drivers for e-business, the innovation-decision process is one through which an individual (or group) passes from

- first knowledge of the innovation;
- to forming an attitude to the innovation;
- to making the decision to adopt or reject the innovation;
- to implementing the innovation; and confirming the decision taken.

This transition from first knowledge of the innovation to its implementation *measured as a temporal process* encompasses the innovations rate of adoption. This may be affected by various factors relating to the key elements of Roger's theory, including; the specific attributes of the innovation in question - its relative advantage, compatibility, complexity, trialability and observability. Also influential is the type of innovation decision being made including optional/individual, collective/organisational, and authoritarian/hierarchical. This factor parallels the recognition of organisational culture and managerial philosophy as a driver to e-business adoption. As mentioned above, the type of communication channel identified as being mass media or interpersonal networks exerts influence over the rate of adoption – and therefore the type of adopter. Roger's has also identified the nature of the social system: its social and cultural norms, beliefs, values and attitudes, as an influential factor in the rate of adoption.

Roger's diffusion model is a useful starting point for analysing the processes involved in diffusion, and is particularly relevant to the present study due to its explicit recognition of the importance of social and cultural factors on the adoption and diffusion of innovations. However, aspects of the theory must be extended and modified before it can be applied to IT (Bayer and Melone, 1989) and more specifically to e-business within the construction industry. Particularly significant to this discussion on diffusion theory is the need to introduce networked information technology itself as a primary communication channel with particular qualities, which will considerably influence both the innovation-decision process and the rate of adoption. In overcoming the constraints of both time and space IT changes the nature of decision-making, making vast amounts of information available for perusal, consideration and comparison. The diffusion of ideas is no longer bound by its passage from individual to individual in a linear and often hierarchical (in the form of management to employee, or from expert to lay-person) chain of communication but is essentially free to move directly and immediately among members of an organisation or social system. The time-space compression (Harvey, D 1989), and the lateral networked system functions (Castells, M 1996) that information technology provides, and which are central to the coming information society, are crucial to understanding the organisational and financial benefits of adopting e-business. Indeed, the web portal is a primary focus of e-business adoption within the construction industry. Thus, a central aspect of the model being developed in the current research is the acknowledgement of the capacity for e-business to improve supply chain integration, and vice versa, supply chain integration to assist in the adoption of e-business.

It is also important to acknowledge the nature of the construction industry supply chain as a social and economic system with particular characteristics. A large percentage of SME's and firms within the construction industry can be classified under the category of late to non-adopters,

which exemplifies the significance of inter-personal social networks within the supply chain for increased e-business diffusion. More precisely, this status identifies the complexity of social networks and the variety of relationships based in trust and social capital currently in existence within the Australian construction industry. These social networks are both fragmented and dynamic – consisting of relationships between firms of both collaboration and competition. Additionally, there are a range of trust-based relationships at play within supply chains and the wider construction industry. For example, relationships of trust grounded in personal (professional or informal relationships) differ substantially from relationships of trust based in the credibility or reputation of a competitor or collaborator. The credibility of a competitor or collaborator significantly alters how a manager of a firm approaches the innovative decision making process; as their first thoughts are *“I trust and value their business decisions even at times without hard evidence”* and therefore place faith in what economic advantages the competitor or collaborator has achieved or potentially seeks to achieve. Similarly, supply chain relationships of trust and collaboration are often created between otherwise disconnected firms that both share a more direct relationship with a mutual party; for example we typically work with similar clients or suppliers. Acknowledgment of this diversity of relationships and shifting scenarios calls for the development of a research model that addresses the complex issue of development of social capital in an environment marked primarily by short-term project based relationships and a competitive ethos.

Walker *et al* (2003) have more recently conducted research into adoption and diffusion of e-business within the construction industry. This research has sought to identify the role of Communities of Practice in enabling ‘knowledge about how to use and adopt innovation initiatives’. At the organisational level it focuses on the ‘absorptive’ capacity of firms as central to building up a knowledge base that can be drawn upon to understand and develop innovations. At the individual level it focuses on information gatekeepers who provide an interface between the firm and an external ‘knowledge bank’ composed of academia and expert knowledge. This research draws upon Roger’s diffusion theory and extends it to functionalise ICT as both the innovation and a means for diffusing the innovation within construction firms, and thus provides a useful reference point for the extension of these theories across the supply chain that is the purpose of the current research. Of interest is Walker *et al’s* (2003) identification of four ‘variable clusters of factors’ that influence the innovation diffusion process within firms consisting of Individual, Environmental, Management and Technology factors. While these factors may eventually be of limited impact in relation to the supply chain, they do acknowledge the complexity and interrelation of various influences on both the organisational and the individual roles in the diffusion of innovations process.

Alongside these extensions and modifications of diffusion theory in order to make it applicable as a framework for investigations into the adoption of e-business in the construction industry, there are other limitations to Roger’s diffusion model. Bayer and Malone (1989) argue that Roger’s theory of diffusion is oversimplified in terms of a binary dualism of ‘adopt’ or ‘not adopt’. There is no means for the analysis of cases where innovations are partially adopted or explanation offered as to why innovations are adopted in some form other than the one intended by the developers of the innovation. Alongside this main methodological deficiency Bayer and Malone (1989) also identify the lack of differentiation between adopting an innovation at a firm level and at an individual user level, and also the failure to consider adoption and diffusion as a function of interactions between various social systems.

Roger's tendency towards a simplified binary conceptualization of the adoption process is considerably problematic in that it does not address the complex nature of the construction industry, nor takes into account the intrinsic flexibility and multi-functionality of information technology and e-business. It is proposed that in the construction industry it is difficult to place firms into one definite category because adoption is not simply an either/or situation. The diversity of e-business applications and also the competitive nature and fragmented structure of the industry - grounded simultaneously in project-based relationships of close collaboration with limited time frames - introduces the notion of discontinuance. Collaborative relationships between firms within supply chains are not permanent, but both dynamic and transient. In considering adoption and diffusion within supply chains, our research model acknowledges that adoption of e-business for one project and in collaboration with a particular group of firms to form a supply chain does not necessarily translate to the utilisation of e-business methods permanently. Rather, each supply chain exerts its own pressures on collaborating or competitor firms, and these pressures are unique to the supply chain in question as a product of the specific project requirements and the organisational and communicative practices of participating firms.

Whilst Roger's five adopter categories provide a spectrum of adoption *rates* from innovator to laggard, these are a function of *time* and do not accommodate differential *modes* of adoption. Of relevance to this point is recognition of the different functions of firms in the supply chain, and accordingly their substantially diverse organisational structures. Associated with this point are also various different interests and perspectives that occur at different levels within both a firm and within the tiers of the supply chain - upstream clients, downstream suppliers and market competitors. Related to this flexibility in mode of e-business application at the level of organisation is also the need to recognise the relative autonomy of individuals within firms. The diffusion of an innovation through a firm is not simply a managerial decision carried out by the firm's employee's, but rather individuals have a certain capacity to determine to what extent the innovation (e-business application) is used efficiently and effectively in relation to their specific role within the firm (Frank, Zhao and Borman, 2004). In this sense, it is possible to account for both partial adoptions within firms, and also alternative (and often creative) modes of adoption.

This more complex reading of the adoption and diffusion process overcomes simultaneously Roger's simplistic binary of adoption/non-adoption, and his emphasis on the temporal rate of adoption in the categorisation of adopter types. This is achieved while maintaining his insights into the influence of the social system in both the form of operating and structural pressures from the supply chain, and also in the circulation of social and cultural meanings and values that influence the development of positive or negative attitudes towards e-business applications. Furthermore, the present research allows a degree of differentiation between the adoption of an innovation by an individual user and at an organisational level and thus facilitates the analysis of cases where innovations are partially adopted or are adopted in some form other than that proposed by the developers of the innovation. The individualised interpretation of a given innovation is relative to both the social and cultural meanings prevalent in the firm, but also to the particular requirements of the role of that individual within the firm (and of the firm within the supply chain).

In this sense, we suggest a more sophisticated conceptualisation of the nature of the innovation is needed, alongside a more individualised analysis of the diffusion of the innovation throughout the social system that acknowledges that the innovation can be changed each time it is communicated or diffused, and that e-business lends itself particularly to diversified modes of application. In the

next section key aspects of the developing model are discussed, being the elements of the innovation, and the channels of communication through which it is diffused.

The Elements of the Innovation

While Roger's diffusion theory acknowledges that different innovations will have different attributes dependent on their form and function, we argue that the consideration of the innovation as a unified and singular entity contributes to a reductionist and simplified perspective on diffusion. Roger's definition of the innovation consists simply of an idea, practice or object that is new. There is no consideration of the component elements of the innovation, nor is there recognition that frequently an innovation consists simultaneously of a new idea, facilitating objects (technologies) and associated practices (also new ideas) – which is the case with e-business. To address this deficiency we have developed a model of the innovation complex: An innovation is composed of three primary elements: concept, material form and operating knowledge (refer to Fig. 1.0). The concept is the idea or notion of the innovation, which includes an understanding of the advantages that it offers. It involves an understanding of the concept in relation to a network of other concepts. The material form exists in the physical form of the innovation, which could be a piece of hardware or software. The operating knowledge is the set of ideas that explain the correct use of the material form or concept. These three elements together make up the innovation complex.

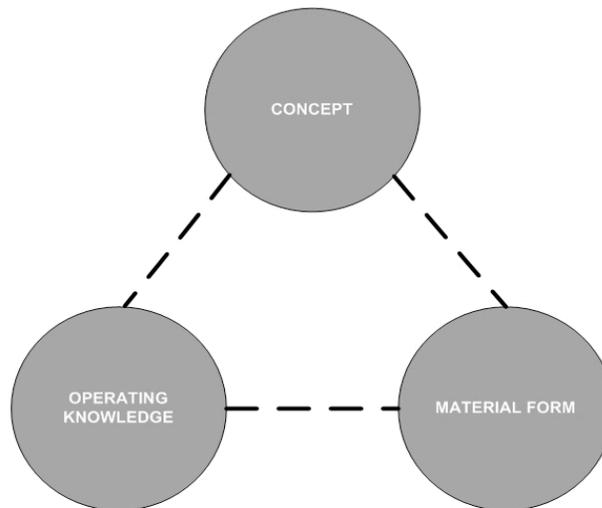


Fig. 1.0: The elements of the Innovation

However, the inter-relationships between the elements are not stable or secure but must be maintained for the effective diffusion of an innovation. This potential for the inter-relationships to be severed is called detachment, whereby total detachment of the elements leads to fragmentation. It is proposed that different elements of the innovation complex are of differing

levels of interest relevant to individuals due to their specific roles in firms, and also each element is affected separately by individualised barriers relating to the circulation of meanings, values, perceptions and attitudes within the social system. Therefore diffusion of the innovation complex through the firm or supply chain may potentially exhibit a tendency towards detachment of its component parts simply due to its communicative passage through individuals with differing interests and interpretations.

Modes of Communication

Roger's definitions of heterophilic and homophilic means of communicating are central to our model of reflexive capability of firms in relation to e-business diffusion. In order for the diffusion of e-business to filter vertically as well as horizontally in individual businesses as well as vertically and horizontally in the supply chain, it is important to analyse the way communication works between individuals. Diffusion of any type of knowledge involves two forms of communication. These can either be *heterophilic*, where two or more individuals interacting have different attributes, beliefs, education and social status, or *homophilic*, where two or more individuals are similar in their attributes and social status. Most communication is more effective when it is homophilic, where people share common beliefs, meanings and have mutual understanding of one another. Individuals enjoy the comfort of interacting with those who are similar. Communicating with those of a different social status requires more effort to make communication effective. Individuals who attempt to communicate with others who are different from them often face frustration and ineffective communication. Communication within the social system is thus shown to be a complex scenario involving differential meanings, practices, values and interpretations depending on an individual position within a company and also the firm's role within a supply chain.

We do not consider that homophilic and heterophilic communications can be so certainly prised apart and demarcated in practice, and there exists a very real capacity for movement between these two modes of communication dependent on both the preferences of individuals and needs of specific situations. However, it is suggested that the construction industry will be based in predominantly homophilic communication as a social system that shares the same general attitudes and perspectives due to roughly similar work needs and organisational requirements. Indeed, most diffusion networks are homophilous, and in this sense there should be, according to Roger's descriptions of homophilic communication and diffusion, rapid dissemination and adoption of innovations within the industry. The case remains, however, that the construction industry lags considerably in taking up e-business. In this regard, it is important to note that while homophily offers 'smooth' diffusion of ideas, it does not necessarily denote acceptance of new ideas or practices – instead homophilic communication can act as an invisible barrier to the diffusion of innovations. New ideas usually enter a system through higher status and more innovative members. A high degree of homophily means that these elite individuals interact mainly with each other and the innovation does not trickle down to non – elites. Homophilous diffusion patterns cause new ideas to spread horizontally, rather than vertically.

However, Rogers sees the importance of heterophilous communication for diffusion as it can often connect two cliques, thus spanning two sets of socially dissimilar individuals in a system. This is especially important in spreading information about innovations. Although homophilic communication may be frequent and easy, it is not as crucial to the diffusion process as less frequent heterophilous communication. Homophily may accelerate the diffusion process but it

limits the spread of an innovation to those individuals who are already connected within the same strata of the social system or interpersonal network. The diversity and fragmented nature of the construction industry and the project-based relationships of collaboration/competition that form most readily within a supply chain do however act to encourage dissimilar firms and individuals into contact with one another. Thus while acknowledging the homophilic communication prevalent in the construction industry as a whole, the supply chain can act to promote heterophily. It is in this sense that the present research proposes that adoption of e-business within the supply chain can act to promote the adoption of e-business within the construction industry.

Diversity of function is the very nature of the supply chain and, accordingly, there is a high potential for different businesses, with different organisational structures and with different goals to work together and adopt innovations. In particular the short-term nature of project-based relationships and cyclic relationships of trust grounded in competition/collaboration mean that the supply chain is a potentially privileged site for the examination of how heterophilic communication can act to overcome the insular and conservative aspects of the construction industry and therefore increase both the rate of e-business adoption and, encourage creative modes of adoption, within the construction industry.

A Reflexive Capability Model for E-business Adoption

The reflexive capability model focuses on the importance of communication, social networks and social, cultural and economic capital for increased awareness and diffusion of e-business within supply chains. In acknowledging the different scales (supply chain, firm, and individual) which influence adoption processes and diffusion of e-business across supply chains, this research model sees adoption and diffusion of e-business as a function of the complex and potentially contradictory interactions of members of the social system. This is the case at both the level of the firm within the supply chain and also of the individual within the firm. Reflexive capability refers to the ability to identify, understand and measure processes and behaviours in a dynamic environment. The conceptual framework outlined above demonstrates that the diffusion of innovations is about change, and that the context for diffusion is a series of scaled dynamic environments (refer to figure 1.2).

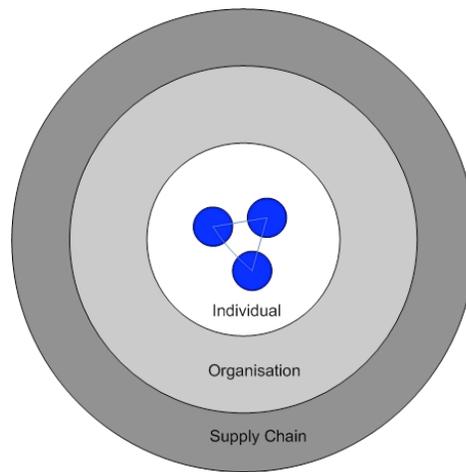


Fig 1.2 – Scaled Contexts

The innovation itself is both complex and dynamic, in that it is comprised of identifiable component parts organised relative to one another through unique, and malleable, relationships. Changes in the nature of those relationships influence the nature of the innovation. As simultaneously knowledge, material form and practice, the nature of the innovation is dependent on the individuals and communication channels through which it diffuses. By definition the innovation is also something new – it implies a change to the way a firm does business, and diffusion implies alterations in the organisational structure and culture of the firm. However, the firm is not an isolated entity, but rather exists in complex relationships of collaboration and competition with other firms to form the supply chain. The above discussion has demonstrated that the supply chain is also a complex and dynamic environment. Thus the reflexive capability model acknowledges this complexity and provides a means for measuring change within this dynamic and multi-scaled scenario.

It is based upon the premise that the behaviour and attitudes of firms towards technological innovations can have significant influence on the acceptance and ultimately the dispersion of e-business by other firms within the supply chain. Although it is important to be aware of the structural drivers and barriers to e-business, our research focuses on the importance of diffusion within and between businesses and the interdependencies between upstream and downstream markets along the supply chain for the adoption of e-business. Rather than taking the approach that a firm either adopts or doesn't adopt we are suggesting that adoption and ultimate dispersion across the industry is based upon firms being along a continuum of “reflexivity” relying upon e-business awareness, responsiveness and adaptability attributes.

The Reflexive Capability model (London, Chen and Bavinton, 2005) is a means of identifying descriptors and characteristics of the different firms positioned within a spectrum of implicit – explicit adoption of e-business technology. The model was developed by the authors for a research project into the internationalisation of construction and design firms and proved valuable in identifying the underlying forces that influence changes in processes and practices. We propose to apply the Reflexive Capability model so that we can develop an adoption profile specifically for the construction industry supply chain that accounts for social-cultural, organisational-structural, communicative and economic (market and supply chain) barriers, influences and pressures to adopt e-business.

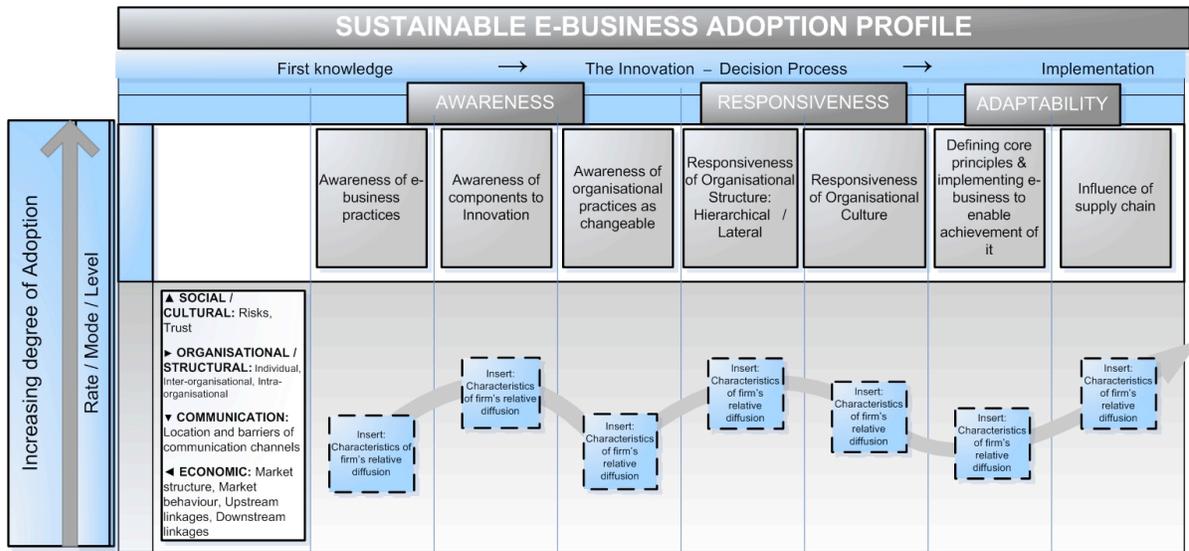


Fig 1.3: Reflexive Capability Model

The Reflexive Capability model measures the *degree* of adoption – a conglomerate indicator that comprises the:

- *rate* of adoption (the relative time in which the firm adopts the innovation),
- *mode* of adoption (the variable form in which the innovation is adopted) and
- *level* of adoption (the extent to which adoption of the innovation changes the processes and practices of the firm).

These variables are indicated by the continuum on the left hand side. Across the top of the model is a series of key attributes in reflexive capability comprising awareness, responsiveness and adaptability. While discrete conceptual categories (and containing within them seven sub-attributes), these categories indicate points in a spectrum that coincides with the innovation-decision process – moving from first knowledge of the innovation to implementation of the innovation. While arrayed in a linear form for the purpose of the model, in reality this spectrum has no discrete start or finish, but rather the last sub-attribute – influence of the supply chain – is in fact a crucial element in determining the nature of the first sub-attribute – first knowledge/awareness of e-business. The process is cyclical and interrelated.

Within a box on the left hand side are the dimensions of the phenomenon under investigation. In relation to the adoption of e-business within the supply chain these are;

- social-cultural factors (the social system, meanings, values and attitudes),
- organisational-structural factors (qualities of both the firm and the supply chain that influence process and practice),
- communication factors (including both the type of communication channel and the mode of communication as heterophilic or homophilic or a combination) and

- economic factors (market structure, market behaviour and upstream/downstream linkages and associated pressures and relationships).

The variable field created by the cross referencing of these sets of dimensions, variables, and attributes allows the plotting of the firms position relative to a dynamic context and thus produces the adoption profile specific to firms within the construction industry. It is essentially important to note that these boxed positions are themselves interrelated and thus open to influence by neighbouring positions. The curve thus defined is the adoption profile – unique to the firm in question, and providing a description of the extent of e-business adoption and diffusion that is relative to the strategic objectives and goals of the firm.

Through application of a reflexive capability model the current research seeks to identify the underlying causes that encourage individuals or firms to move between the different stages of diffusion/adoption. In doing this it will be possible to highlight the characteristics of the different types of construction SMEs in relation to the differential levels, modes and rates of adoption as well as to identify the particular organisational and socio-cultural characteristics of firms that acts to encourage (or discourage) the innovative diffusion of technology. The conceptualisation of the innovation itself as complex, differentiated and potentially detachable draws attention to the various circulations of meanings, values and perceptions within a social system that may produce highly individualised barriers to diffusion at all levels of the firm. The emphasis on communication provided by the reflexive capability model will make it possible to identify the dominant types of communication channels operating within firms and between firms within the supply chain. Accordingly the current research hopes to be able to ascertain the type of communication – heterophilic or homophilic – that best facilitates diffusion within firms and the supply chain.

In relation to the influence of supply chain structure and organizational and communicative practices upon the adoption and diffusion of e-business the present research will examine the attitudes/perceptions towards e-business in operation at the different levels/firms and identify the processes and informing values, ideals and meanings by which they are formed. Similarly, we will investigate different barriers/drivers related to construction industry players at different levels (tiers) of the supply chain. It is proposed that the existence of shared perceptions and attitudes between firms will increase the likelihood of shared barriers; however this will be affected by the type of clusters the firms located in. Are they tight and competitive, composed of innovator market leaders, all SMEs? The diversity of firms and relationships of both collaboration and competition within the supply chain invites research into the economic and/or social pressures from upstream/downstream players who adopt or don't adopt, and how these pressure contribute to awareness, ability to respond and ability to be flexible. Conversely, we intend to establish the economic pressure that a firm may face which encourages/discourages adoption in relation to their competitors in the construction industry.

Future research and summary comment

A case study methodology will be used to test and validate the proposed research model. Three case studies of the construction portals and associated clusters of consultants, contractors and suppliers will be investigated in-depth to determine the constraints and underlying causes to e-business adoption by SMEs in the building sector and by large suppliers and contractors in the civil sector. The aim is to develop a comprehensive technology adoption profile specifically for

construction industry players. The portals are associated with three firms that are involved with the uptake of e-business in some form or another whereby each case study has unique characteristics with respect to its stage of e-business technology adoption.

The key source of data will include semi-structured individual and focus group interviews with targeted personnel associated with e-business adoption at various levels (individual, organisational and supply chain). This is to gain a range of perspectives of partial/late-adopters to early adopters. Senior managers of suppliers, consultants, subcontractors and contractors associated with the focus firm's portal will be interviewed individually to identify from the SME perspective the difficulties and successful strategies used in e-business technology adoption. The focus group interviews will involve internal staff of the focus firms to develop the context of the problems associated with working online with their various consultants/suppliers/subcontractors/contractors and gain insight of the barriers and drivers from the client side of the construction portal.

The analytical methodology will be drawn primarily from the research perspective of grounded theory (Strauss and Corbin 1990, and Glaser, 1992), which will be used as a means of data organisation and theory generation. Each case study will be analysed as an independent unit and subjected to two stages of coding and analysis. The first stage will be open coding involving the loose association of themes and concepts as revealed by the individual transcripts. Preconceptions as to what the data will reveal should be minimised in order to allow the themes present in the data to emerge naturally rather than be projected onto the data by the researchers. The second stage will be 'axial coding', involving the arrangement of data according to dominant themes that have emerged. Eventually this mode of analysis will be extended to comparative analysis between case studies in order to ascertain common themes and irregularities and to enhance the potential for generalisation of the resultant theory. The project is due for completion in December 2005.

This theoretical paper has examined the relationship between economic, social and cultural aspects of innovation and the capacity to increase the diffusion of e-business in the construction industry supply chain. It has identified the need to not only consider the structural barriers and drivers to innovation but also the significance of diffusion within and between businesses and the supply chain for the adoption of e-business. The present study will identify the barriers/drivers/perceptions that the different groups have in relation to e-business barriers – the perceptions of the adopters on one side and non-adopters on the other, based on the same set of barriers, and thus providing a more totalized understanding of both the nature of the barrier and appropriate strategies to overcome it. Furthermore, it will establish the interrelation of economic, social, cultural, organizational and communicative factors and practices on the adoption and diffusion of e-business. The research is unique in its acknowledgement of the dynamic, complex and multi-scaled contexts influencing the adoption of e-business within the construction industry. It is also unique in the development and application of a reflexive capability model that is specifically designed to account for changes in dynamic environments. Research into the adoption and diffusion of e-business within the construction industry is both timely and valuable. The present research intends to make a significant contribution to this field of endeavour.

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