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**Network Learning in a High-Tech SME:
Expanding Entrepreneurial Capabilities**

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Abstract

This paper examines the process of learning, both technological and organizational, which has taken place in this small-sized firm located in a relatively remote area of northwest England. With relations to supply chain management and innovation network theory, it is argued that it is the relational elements of inter-firm transactions and interactions that provide organisations with opportunities to expand their capability. The importance of supply chain management, therefore, is that it provides a process in which closer relations are both desirable and can potentially create opportunities to grow organisational capability. The paper is focused on the following aspects of learning: the first is the evolutionary nature of the accumulation of technological capability; the second is the firm-specific absorptive capability developed through its close relationship with BNFL and other firms within the supply chain. The case study organisation is instrumental in building a network of suppliers and customers, which has enhanced the learning opportunities and capabilities of both. In doing so, it has created virtual clusters of innovation through the supply network that reach well beyond the traditional regional institutional support mechanisms.

Introduction

Over the last two decades, strategic restructuring programmes within large organisations and the intensification of competition have resulted in a focus on supply chain management as a potential source of competitive advantage. Supply chain management is concerned with the drive for greater efficiency and effectiveness through the creation of more integrated business systems to manage customer-supplier relationship. Consequently, effective supply chain management involves establishing closer working relationships to add-value and build strategic capability (McDermott and Chan, 1996). The legal or contractual obligations on which supply chain relationships are based cannot in themselves lead to the open exchange of knowledge and information. To fully realise the benefits of working with other firms there must be focus on the procedural interactions that encourage closer collaboration through reciprocity and trust. Indeed, networks are complex and it is the diversity of actors and relationships that provide the opportunity for knowledge creation and sharing (Conway and Steward, 1998).

North and Smallbone (2000) argue that there is no clear evidence that, in terms of innovation and technological learning, firms in remote rural areas lag firms in more accessible rural and urban areas. Rather, variance in innovativeness is due to firm-specific factors such as managerial capabilities and broader sectoral influences. Yet, influential work on industrial clusters and regional development indicates that interaction with other firms plays an increasingly important role in expanding competences and competitiveness. (Porter, 1998a/b; Lundvall, 1992; Hakansson, 1987). The geographical reach of most supply chains provides a wide range of learning opportunities that extend beyond the firm's immediate locality. However, creating an environment that encourages innovation based on network relationships require that managers conceptualise a competitive space that extends beyond geographical areas to take advantage of 'virtual' links based on information and communications technologies (ICTs) (Romano et al, 2001).

This paper examines the development of technological and organisational competences in a small, high-technology manufacturing firm (32 employees with an annual turnover of approximately £4.0 million in 2002). Our aim is to explain how

innovation, both technological and organizational, has taken place in *Romar Workwear Limited* despite its location in a relatively remote area of northwest England. The relevance of the firm's rural location and its relationship with the region's only large multinational corporation are explored to explain Romar's rapid growth in size and technological capability over the last five years. The absence of other firms with similar levels of skill, knowledge and aspiration means that supply chain relationships, both national and international, have been key to improvements in competitiveness and innovation. Romar have acted as a 'knowledge integrator', facilitating knowledge exchanges between different levels within the supply chain. We begin with an examination of the supply chain literature and follow this section with a discussion of entrepreneurial and innovation networks. After a brief outline of the research methodology the empirical data are presented. We then examine the implications of this case for the growth of small firms through the medium of virtual clusters.

Improving Competitiveness Through Supply Chain Management

Competitive pressures have created an increasing pressure to reduce costs and improve competitiveness through the development of integrated supply networks. Davis (1993) argues supply chains must be viewed, not as series of interlocking firms, but as whole systems, *a gestalt*. Indeed, in a recent literature review, Tan (2001) notes the integrative nature of supply chain management. The paradox, Tan notes, is that the most effective strategic response to shortening product lifecycle and intensified competition is to develop long-term supplier relationships to improve quality and innovation. Moreover, increased rationalisation within large firms and the increase in outsourcing make the supply chain an important source of both competitiveness and competence.

While Prahalad and Hamel (1990) argue for an organizational focus on core competences and the outsourcing of peripheral activities they also add a note of caution. Outsourcing may improve competitiveness, but there is a danger that it may also lead to the transfer of competences that are essential for product leadership. The dilemma is that a focus on core competence means it is essential that those competences are constantly renewed. Moreover, outsourcing may reduce the ability to assess and access new competences and knowledge. Taking this argument further,

Brusoni and Prencipe (2001) propose that the continuing specialisation of knowledge will make firms' external relations even more important. Innovation in an era of rapid technological change requires the adoption of loosely coupled, inter-organisational structures that encourage the management of specialised knowledge. At the same time, systematic incorporation of new knowledge requires the development of the firm's absorptive capacity to encourage effective dissemination and exploitation. This ability to use new knowledge effectively is the key to organisational learning and the creation of core competence (Powell et al, 1996). The proliferation and integration of information through ICTs 'has altered the nature of existing relationships of intermediation in ways that have facilitated a much wider collection of organisational forms' (Cox *et al*, 2002:154). If that is the case, then a more embedded supply chain is essential to provide wider opportunities to retain and renew strategic capabilities through constant evaluation of knowledge that can potentially add-value.

Inter-organisational networks based on depth, quality and diversity are the most important source of new knowledge (Conway and Steward, 1998). As Castells (2000:188) asserts, the network enterprise '*transforms signals into commodities by processing knowledge*' (emphasis in original). The significance of tacit knowledge in the innovation process (Nonaka and Takeuchi, 1995) and the external environment as a source of knowledge (Drucker, 1985; Rothwell, 1992) also highlights the importance of effective inter-organisational networks. This resonates strongly with resource-based perspectives on strategy where sustained competitive advantage is based on resources that are rare, imperfectly imitable and non-substitutable (Barney, 1991; Boxall, 1991; 1996). Indeed, Croom *et al* (2000) develop a framework that captures the dimensions of inter-organisation relations including: level of analysis, dyadic, chain or network, element of exchange, assets, information, knowledge and relationships. By classifying the literature in this way, they focus attention on the variety and complexity of inter-organisational relationships through which value can be added. Moreover, Nesheim (2001) contends that empirical studies support the argument that the firm's strategic core is strengthened through transactions with suppliers which go beyond traditional market-based interactions. Although the resource-based view of strategy generally focuses on the quality and complexity of an organisation's internal resources, these resources can be upgraded and renewed

through the interactions within business (supply chain) networks. According to Dyer and Singh (1998:662) building competitive advantage depends on extensive external linkages:

'relational rents are possible when alliance partners combine, exchange, or invest in idiosyncratic assets, knowledge, and resources/capabilities and/or they employ effective governance mechanisms that lower transaction costs or permit the realization of rents through the synergistic combination of assets, knowledge, or capabilities.'

In supply chain relationships then, rare, imperfectly imitable and non-substitutable resources can be developed by collaboration that creates high levels of trust and product knowledge, integrated communication structures and flexible inter-organisational relations. It is through these unique relationships that strategic competitive advantage is realised (McDermott and Chan, 1996; Sinclair et al, 1996; Hoyt and Huq, 2000; Arnold, 2000; Ellram and Billington, 2001; Croom, 2001). However, while the complexity, quality and flexibility of these relationships are difficult to replicate they only provide the *potential* for sustained competitive advantage. Achieving high levels of integration depends on the capabilities and competence within organisations to develop and exploit closer relations (Croom, 2001). It is the ability of firms to provide *both* production and relation management capabilities that is the key to their retention as preferred suppliers. Consequently, supply chain management creates a network of firms which has the potential to enhance the technical capabilities and relationship management skills of all those operating in the network. In the following sections we examine the significance of networks for entrepreneurship and innovation.

Entrepreneurial Networks

The issue of entrepreneurial networks has received increasing attention since Leonard-Barton's (1984) comparison of entrepreneurs from Sweden and the US. During the 1990s a wide range of studies were carried out which added to the broader understanding of the way in which those engaged in setting-up and managing small firms were able to access external resources. In particular, scholars demonstrated an awareness of how, to be effective, entrepreneurs must make use of their networks. For example, Johannisson and Peterson (1984:1) note the apparent paradox that, on one hand, entrepreneurship 'personifies individualism and independence' while on the other hand individuals are 'very dependent on ties of

trust and cooperation'. Leonard-Barton (1984:113) suggests that 'entrepreneurs who, for geographic, cultural or social reasons, lack access to *free* information through personal networks operate with less capital than do their well-connected peers. Inherent in the maintenance of effective networks is the need for entrepreneurs to continually create *weak-ties* to prevent a few strong-ties from closing their network to new ideas and opportunities (Leonard-Barton 1984; Aldrich and Zimmer 1986). Competent entrepreneurs draw on personal networks to extend strategic competences and resolve acute operating problems by supplementing internal resources (Birley *et al*, 1991; Conway, 1997). Creating, maintaining and exploiting a broad range of external linkages is central to the entrepreneurial process:

'Entrepreneurs continuously network as they pursue and react to new realities. While management needs structure, certainty and decision rationality, entrepreneurship thrives on process, ambiguity and action rationality (Johannisson, 2000:368).

Networks are based on social relationships, family, friends, neighbours, as well as customers, vendors and creditors. Birley *et al* (1990:59) note: 'entrepreneurs, at an early stage of enterprise development, rely heavily on informal network of friends, family members and social contacts from the local neighbourhood to gather relevant data'. Gradually, entrepreneurs extend their networks to include bankers, accountants, lawyers, suppliers, government agencies, customers and consultants. Research on the growth of small firms (McGhee *et al*, 1995) confirms the importance of entrepreneurial teams that 'expand the organization's network of contacts and provide the balance of expertise required to profit from certain types of cooperative activity' (Birley and Stockley, 2000: 289). Entrepreneurs with good cultural and social networks can attract higher levels of capital and are more likely to be successful than those with limited networks (Shaw, 1998). Some linkages are planned, some are accidental and others with organised groups, such as Chambers of Commerce, help enhance entrepreneurial scope (Bennett *et al*, 2001). In the early stages of a business startup entrepreneurs rely on strong ties gradually building up weaker ties and contacts with 'strangers' as the business develops (Aldrich and Elam, 2000). Larson and Starr (1993) suggest that this process has three stages: focusing on essential dyads, converting dyadic links to socioeconomic ties, and layering the exchanges (incorporating a wider range of business functions). This helps mediate

risks inherent in building a business by opening channels of information that are otherwise inaccessible. In contrast, it is noted by Chell and Baines (2000) that some authors (Blackburn *et al*, 1991; Curran *et al*, 1993) report that small business owners have little time for networking and place more emphasis on independence *via* a 'fortress enterprise mentality'. In explaining the contradictory evidence, Chell and Baines (2000:205) found networking was positively related to business growth being significantly higher in 'expanding or rejuvenating' businesses than those 'plateauing or declining'. 'Entrepreneurial networks' help owner-managers strengthen their business by providing access to scarce resources including skills, information and knowledge. The more general term 'innovation network' refers to linkages that are established to supplement internal resources in the development of new products, services and processes. In smaller firms there are many overlaps between entrepreneurial and innovation networks.

Innovation Networks

In recent years writers from a range of disciplinary areas have adopted or utilised the term innovation network. However, despite the many network studies, varying from industrial districts (Piore and Sabel, 1984) to detailed microsociological approaches (Granovetter, 1985; Steward and Conway, 1996) there has been little attention devoted to analysing 'the detailed structuring of those relationships' (Sobrero and Schrader, 1998). In an attempt to resolve this problem the authors suggest that there are two dimensions which are 'fundamental' to the management of inter-firm relationships: contractual and procedural coordination. Contractual coordination refers to the legally defined exchange of rights (Stinchcombe, 1990; Williamson, 1985) while procedural coordination refers to the structural mechanisms that are necessary for the exchange of information and organisational learning (Nonaka and Takeuchi, 1995). The separation of organisational responsibility means that senior managers and lawyers are responsible for contractual coordination and business unit managers and functional managers (R&D) are responsible for procedural coordination. Sobrero and Schrader (1998:590) quote Doz *et al* (1989:136) who state that actual coordination is achieved not through contractual means but by patterns of communication involving individual employees: 'Top management puts together strategic alliances and sets the legal parameters for exchange. But what actually gets

traded is determined by day-to-day interactions of engineers, marketers, and product developers'. In other words, there is emphasis on the processual elements that underpin the exchange of information and knowledge. Coordinating activities are related to the distinction between uncertainties about the means needed to attain a particular goal and uncertainties about the goal itself (Thompson, 1967). The level of uncertainty combined with issues of 'asset specificity' has direct implications for the structuring of relationships between cooperating organisations.

Studies of internal technological and organisational change (Arrow, 1962; Aoki, 1986; Rosenberg, 1982) emphasise routines and learning-by-doing. Research on the ability of firms to access external learning stresses the importance of environmental factors and learning-by-interacting. (Porter, 1998a; Lundvall, 1992; Hakansson, 1987) The external learning approach is closely related to studies of industrial and spatial clusters (Porter, 1998a; Krugman, 1991; Storper and Walker, 1989). Such authors argue that geographic proximity attributes to the effect of knowledge spillovers (Koschatzky, 1998) and especially the acquisition of tacit knowledge that is considered critical to the firm's competences (Nonaka and Takeuchi, 1995). Much of the literature associated with regional innovation networks has used the development of high-technology sectors in California as a key reference point. In her analysis of a key new technology cluster Saxenian (1991, p424) states: 'Silicon Valley demonstrates how inter-firm networks spread the costs and risks of developing new technologies and foster reciprocal innovation amongst specialist firms'. More recently, Koschatzky (1998, p385) notes that studies carried out in the US using patent data or the Small Business Administration census 'reveal proximity effects in the innovation activities of industrial firms, universities and business services'. The identification of high-tech regions has implications for policy-making as national governments try to replicate the successes of Silicon Valley, Emilia-Romana and Baden-Wurtemberg. Porter (1998a: xxiii) has been particularly influential suggesting there is 'mutual dependence' between government and business because 'many of a company's competitive advantages lie outside the firm and are rooted in locations and industry clusters'. It appears, however, that most empirical studies were carried out in industrial districts of advanced nations and regions with high concentrations of customers, suppliers, capital provision, and supporting services (Saxenian, 1994; Hakansson, 1987). Even studies on less-

favoured regions in industrialised nations (Cooke and Morgan, 1998) show that firms are provided with opportunities to become members of regional industrial clusters and innovation networks. In stark contrast, firms in certain regions are geographically disconnected from such industrial clusters and lack opportunities to benefit from interactive learning.

So far, literature related to ‘virtual networks’ tends to concentrate on technical factors rather than social issues. For example, Romano *et al* (2001:19) suggest that a ‘virtual cluster’ is ‘an ebusiness community, made up of customers, suppliers, distributors, and commerce providers sharing digital and knowledge networks for collaboration and competition’. The authors go on to argue that it is ICTs in general and the adoption of digital networks in particular that have generated a new kind of collaboration and competition. Furthermore, they propose that forming virtual clusters depends on firms implementing the principles of supply chain and customer relationship management. These must be reinforced by the development of appropriate technological platforms and service providers. In contrast, our approach to virtual clusters analysis takes a social interactive perspective in which attention is focused on tangible supply chain and customer relationships without overstating the virtual effect of ICTs. By tangible we mean the utilization of conventional communication channels like meetings, telephones and air travel for customer relationship management rather than online digital communication. We do acknowledge that both supply chain management (SCM) and customer relationship management (CRM) are building blocks for the formation of virtual clusters. These arguments will be developed in the following sections which present the empirical data.

Research Methodology

As described in the introduction section, the company, Romar Workwear Limited is located in Cumbria, a rural area of northwest England. In fifteen years the company has developed from an entrepreneurial team (consisting of one full-time and two part-time employees) to a small, successful, hi-tech manufacturing company employing 32 staff. The company’s core business is based on the supply of personal protective equipment (PPE) to BNFL’s Sellafield plant and several other sites. During its expansion, the company has developed managerial competences and

expanded technological capabilities by vigorously fostering supply chain relationships. Having established a secure business, the management team now face the challenge of continuing growth in the face of institutional barriers created by the absence of a 'scientific pole' (universities and research centres) which is central to the creation of techno-economic-networks (Callon, 1992). In addition, there are significant geographical constraints including inadequate infrastructure such as poor quality road and rail transport links. Creating a 'virtual cluster' by networking beyond the locality through regional and global supply chains have helped compensate for limitations within the region.

Our interest in Romar arose during a European Social Fund (ESF) project auditing managerial competences in small firms operating in the supply chains of larger organizations. While in search of firms that had demonstrated excellence to inform the development of an audit instrument and to identify relevant competences to benchmark, Romar was recommended by both staff at BNFL and the Northwest Regional Development Agency. Their success had been recognised by BNFL in their award of two Supply Network Innovation Prizes (SNIP). The audit conducted as part of the ESF project placed Romar at the top of all 39 companies in the study. Thereafter, in addition to the analysis of company data such as financial reports, records of meeting and strategy presentations, we conducted four interviews with the commercial director and three interviews with the technical director over an 18-month period. During this time they won a new contract as the single-source supplier of PPE to BNFL Sellafield. The commercial director is responsible for the strategic development and organization of business and marketing activities and the technical director is responsible for the development and innovation of production and supply items. Access to company information was very open and included strategic plans and the outcomes of strategy meetings outlining the intention to build closer supplier networks. This information was triangulated with data collected from a senior purchasing manager in BNFL and from Respirex Ltd. The BNFL purchasing manager had been responsible for the co-ordination and management of the supply contract with Romar for over five years and had seen the company's growth at first-hand. Interviews with Respirex staff included the sales director and the technical director who had worked directly with Romar on the development and supply of air-fed protective suits to BNFL.

We accept that there are limitations to single case studies in terms of the extent to which results can be generalised. Nevertheless, it is our view that the value of in-depth cases out-weighs such limitations. For example, Monge (1995:268) points out that despite ‘much exhortion’ to conduct longitudinal studies ‘the percentage of published research articles that report data collected at more than one point in time is minuscule.’ Ogbor (2002:623) is critical of reliance on quantitative methodologies ostensibly based on neutral, objective and value-free social science that dominate studies of entrepreneurship. Instead, he calls for qualitative approaches in which there is an ‘intimate collaboration between facts and theory’. It is suggested that adopting a detailed case study approach allows researchers to observe a ‘chronological sequence’, which helps to ‘determine causal events over time’ (Yin, 1994). Our view is that establishing causality in highly complex social organisations is extremely difficult whatever methodology is adopted. Rather, we concur with Barley (1986:81) who argues that mapping ‘emergent patterns of action’ demands a detailed qualitative approach: ‘Retrospective accounts and archival data are insufficient for these purposes since individuals rarely remember, and organizations rarely record, how behaviors and interpretations stabilise over the course of the structuring process’. In discussing the shift from micro to macro levels of analysis Hamel *et al* (1993) argue that the objectives are more important than the number of confirmatory cases. This refers to the distinction between statistical generalisation (Yin, 1994), in which inference is made about a specific population, and analytical generalisation, in which empirical data are compared with a theoretical ‘template’.

Technological and Organisational Innovation

Two former employees of BNFL established Romar in 1987, one of whom remains with the company. The three current owner-directors split their responsibilities between financial, technical and commercial management. They have recently appointed a production director, a sales director and purchasing director (Figure 1). For the first ten years of the company’s operations they were primarily a manufacturer of PPE. However, in 1997, the company won the single-source contract from BNFL and in 18 months turnover grew from around £800,000 to approximately £3.5m. A large portion of growth was through the supply of PPE items for this contract. The company currently employs 32 personnel and they have begun to

outsource some routine manufacturing, such as sewing, while retaining control of technical knowledge. Apart from the usual performance management criteria, such as on-time delivery, quality and order accuracy, BNFL also requires Romar to rationalise supply items across the organisation and use value engineering to improve products. The awarding of a single-source contract potentially creates a barrier between suppliers and prime contractors such as BNFL (Figure 2). However, the management team at Romar have approached product improvement in three ways. First, they use their previous experience and technological knowledge to engage in active experimentation. Secondly, they seek external expertise from a number of sources, including suppliers. Thirdly, they bring together suppliers and customers to facilitate knowledge exchange through dialogue. It is the last two of these elements that are the focus of this study but they are inextricably linked to the knowledge, experience and creativity within management team.

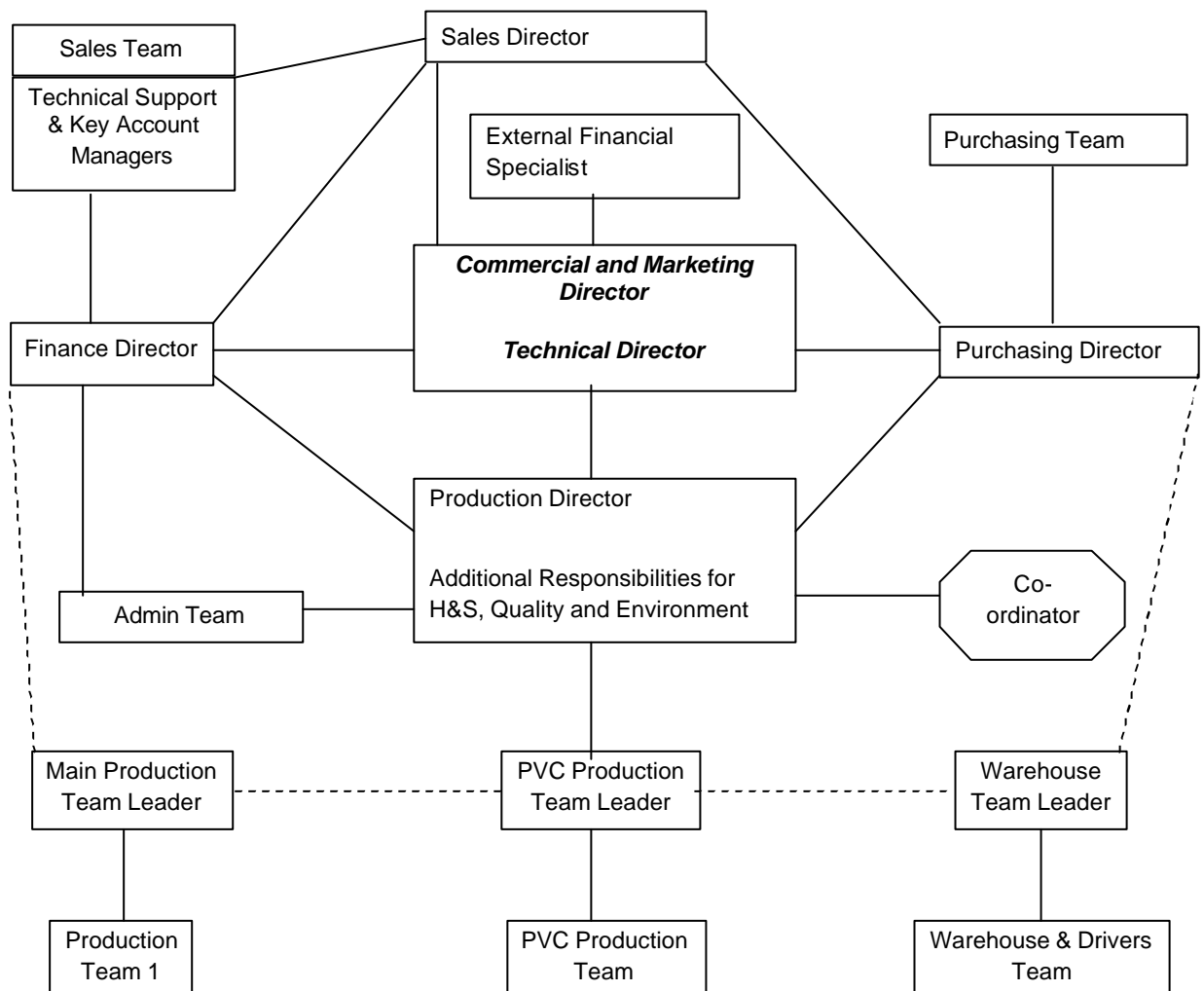


Figure 1. Romar Workwear Limited Organization Chart.

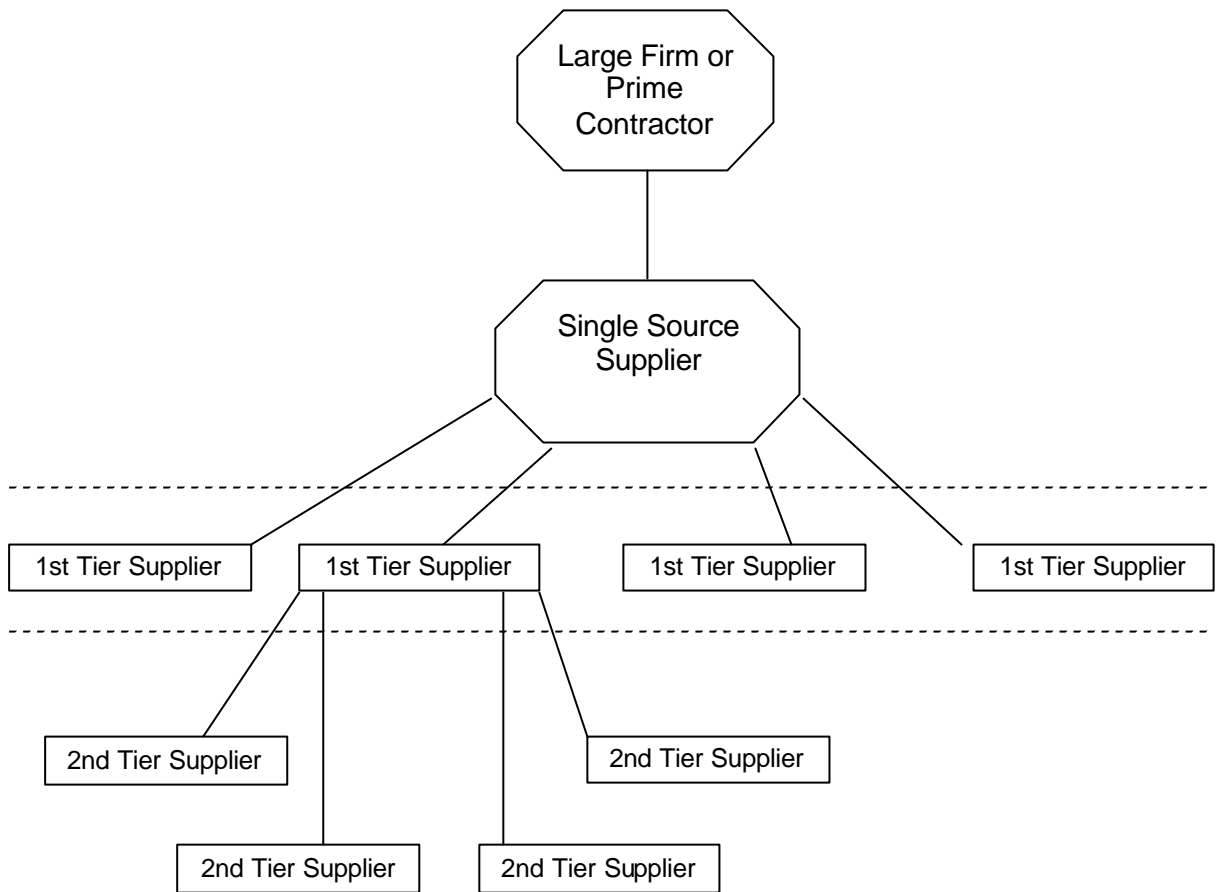


Figure 2. Single-Source Supply Chain

Since in-house manufacture accounts for a very limited number of supply lines (26% of total turnover), value-engineering existing products requires high degrees of collaboration. This involves not only access to the end-users, but also to OEMs (original equipment manufacturers) and OEM suppliers. In terms of technological innovation, this means Romar's directors have sought suppliers with new products and helped them market those products to the nuclear industry. As the commercial director (CD) notes, potential suppliers are not necessarily conversant with the peculiarities of the industry:

'we're looking for a new material... but trying to get them interested in developing it. It's been taking us since August last year [6 months]... and they sent us this really wonderful thing but they put this gel in it, you know like they put in baby's nappies, and when it got wet it all squidged out and that would just contaminate everything... So you've got to try and help them understand what it is and get them to visualise what the problems are... because they don't understand the technicality of what they're doing' (CD)

However, the directors also have extensive knowledge of end-user problems gained through their earlier experience in the industry. They have extended this knowledge through direct involvement in product innovation through regular discussions with key actors in BNFL. This experience is then utilised to assist suppliers:

'My background in actually using the products, i.e., air-fed suits and respirators has helped me in understanding when people are complaining about certain issues... I understand where they are coming from' (Technical Director [TD])

Romar supplies the nuclear industry which is constantly under scrutiny and quality standards are of paramount importance. Consequently, even minor modifications to existing products must be submitted to the Nuclear Inspectorate and BNFL's rigorous testing procedures. Thus, the innovation process is not only technically demanding but also difficult in terms of obtaining approval:

'you can't appreciate how long it takes for them to make a decision and sometimes they leave trials ongoing and then they come back for a scheduled meeting and your suppliers are travelling a very long way... sometimes from Finland, sometimes from the other end of the country... and they come back with no development issues... [so] you've got to motivate the suppliers because they can become very disillusioned where they will be saying, I'm never coming back to this site again' (CD)

During the innovation process and related value-engineering, Romar directors have established a number of close relationships with customers and suppliers. Mutual trust has grown through the exchange of ideas and knowledge with benefits for both parties: 'we are collaborative partners [and]... we share development, time, costs and innovation' (CD). In seeking closer relationships, the attitude of suppliers is as

important as their technical ability. The directors have refused approaches from local companies: ‘they don’t have the same attitude but find me another company that thinks like us, well hey we wouldn’t have a problem with partnering’ (CD). One particular partnership combined Romar’s expertise in the nuclear industry with Respirex’s expertise in air-fed suits. Both companies benefit from their close ties, with Romar becoming sole distributor for the air-fed system to the nuclear industry and Respirex gaining added expertise in the development of their products.

‘John (TD) will always gives guidance because of his experience... he’s been instrumental that we try and get a similar spec that he’s happy with... we couldn’t have done this without John... it’s a two way relationship, 50/50... ’(SD, Respirex)

‘he’s very technical on what they need... we know exactly what each other is talking about when we talk about suits and air systems and such like’ (TD, Respirex)

Romar directors see technological innovation as a company focus that draws on the management team’s strengths. The technical director provides focus for innovation and the commercial director provides business management skills: ‘he’s the person who can go and look at a job and say, “I know just how to create something I can sell them”, John innovates the products and I innovate the business processes’ (CD). One of the company strengths is to provide added-value through specialist knowledge and networks throughout the PPE industry. The focus on knowledge-creation means that Romar directors are willing to outsource lower-value manufacturing activities to other firms: ‘not only do we develop specific products for specific needs but we sometimes take out operations... you don’t have to make the product that you’re going to wear’ (TD). Moreover, they use knowledge gained at visits to customer sites as sources of technological innovation and take suppliers on site visits to demonstrate problems *in situ*.

‘What Romar were able to do was to bring the manufacturer into the demos so they effectively provided the project management service and built up relationships with some key customers who were able to go through a process of identifying a suitable product, piloting the product and then going through the process of replacement’ (BNFL Purchasing Manager).

‘we were actually talking to the guys that put the suits on and it was quite clear that nobody had ever done [that]... had taken manufacturer in there and listened to what wearers wanted and that was Romar, that was John (TD Respirex)

This occurred during a Nuclear Industry Inspectorate safety test when BNFL was having problems with current suits and respirators failing in an extreme conditions test: ‘So I went in and said you need the new suit that I’ve developed with Respirex’

(TD). Subsequently, Romar's TD encouraged his counterpart at Respirex, the manufacturer of air-fed suits, to attend the trial at very short notice and to demonstrate the new suit to BNFL. In addition, modifications were made to the associated respirator with approval of the respirator manufacturer, another firm in the supply network. The demonstration of the new suit and the modifications necessary to the respirator were achieved within 36 hours. The response was only possible because of the close working relationship and trust between their supply network firms and the collaboration between them in product design.

'so we did the innovation of the mask with the special covers, the mask is manufactured here, the suit's manufactured by Respirex in Surrey, the filter's from Scotts [Finland] with a cover that we [Romar] designed, again manufactured at Respirex... so we had a Scotts' product with a Respirex cover on, we had a Respirex suit with a Romar mask and special covers on and the special covers were designed by Romar with Scotts' (TD)

The Romar management team act as knowledge brokers between firms in the supply network as illustrated in Figure 3. They provide direct access to BNFL and break down barriers between the traditional tiers in the supply chain. The grey shaded area represents the knowledge created through the inter-firm collaboration. Romar directors believe they benefit directly since they are continually renewing stores of knowledge and expertise that help differentiate them from competitors. This is one of the reasons they decided to ask for a full re-tender process despite being offered a one-year extension to their existing contract. They believed that they had proved themselves, not only by providing just-in-time PPE supplies, but also by improving technical products crucial to safety at BNFL. In giving free technical advice and building relationships they had established trust and respect:

'so he understood our business, understood the environment we were working within and can actually come with new ideas to solve problems. So as part of the service contract he became a problem-solver for us' (BNFL Purchasing Manager).

'three of the (BNFL) guys on the [re-tender] panel said, you couldn't take this guy away from us because our section would shut. He's my consultant as well as my supplier because I ask him and it's free advice and he tells me what's wrong' (TD).

Romar directors certainly see such collaboration in the development and use of knowledge as a key source of competitive advantage in the future. However, having audited their own activities they recognised that they, as directors, spent too much time dealing with the day-to-day running of the company. This reduced their capacity to innovate new products and develop new markets. By introducing the three senior

(purchasing, sales and production) managers (fig. 1) they believe that they can concentrate on more strategic issues: 'it's enabling me to go out there when a customer has a problem, solve it, get the samples made up and to produce new products' (TD). In this way, restructuring is improving the ability of the management team to contribute to value-engineering and knowledge brokering processes within the supply network by creating 'entrepreneurial resources'.

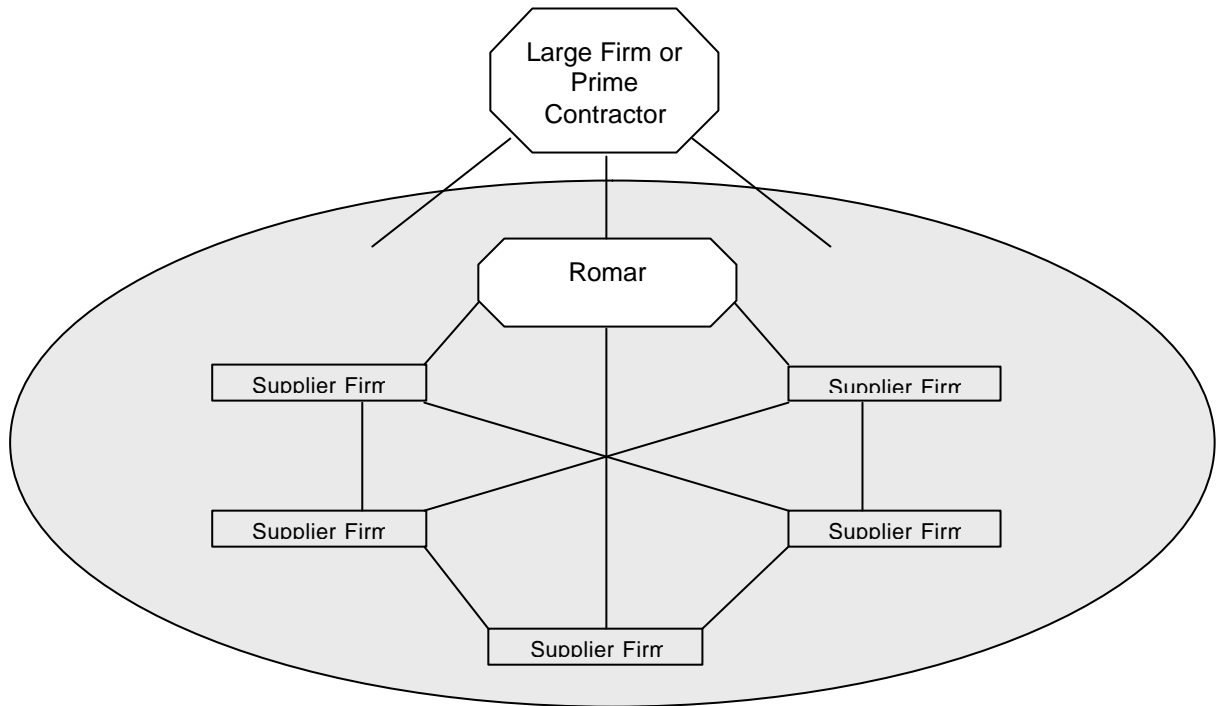


Figure 3. Collaborative Supply Network

As a small company with limited technical and managerial capabilities, innovation relies on the acquisition of knowledge from external sources. One example concerns the development of a protective suit made from lightweight, flexible material. The directors recognised the need for such a suit as a result of their earlier experience in the nuclear industry. Because they lacked expertise in materials the directors contacted Government Business Support Services who were unable to identify any companies specialising in high-technology plastics within the region. Consequently, drawing on their previous experience, they established a technical specification for the material quality in terms of flexibility, strength and performance. It was then sourced, using the internet and business directories, from companies expert in plastics manufacture. A variety of materials were tested and suppliers encouraged to make improvements to meet BNFL's needs. In addition, since it was imperative that the material retained its performance when 'welded' to create a suit, Romar also developed a specialised manufacturing process that ensured the quality of the finished products. In short, through inter-firm relationships and contacts, the Romar management team has improved existing products, encouraged the development of new materials for better products and innovated new products. In their words, 'our job is to put it all together with a focus' (CD).

Discussion: Entrepreneurial Networks and Virtual Clusters

This case study provides an important example of how building effective entrepreneurial networks helps expand a firm's capabilities. In the start-up phase, the two former BNFL employees used friendship links with ex-colleagues to build their new business. Mobilisation of 'strong ties' typifies the way in which successful entrepreneurs make use of their social relationships to create new business opportunities (Birley *et al*, 1990). However, to move beyond the phase of a 'life-style' business it is essential that entrepreneurs extend their networks to draw in new skills, competences and capabilities (McGhee *et al*, 1995; Birley and Stockley, 2000). Romar certainly illustrates the way in which mobilisation of a range of 'weak ties' (Granovetter, 1973) has helped build a very sound business with considerable potential for future growth. These weak ties were formed through searches for innovative products and materials within the supply chain. Thus, the weak ties were a source of new knowledge and knowledge spillover (Koschatzky, 1998) highlighting

the importance of 'loosely-coupled networks' where key firms, staff and systems act as knowledge integrators (Brusoni and Prencipe, 2001). Romar has the authority, as a single-source supplier to BNFL, to integrate new knowledge from a range of sources both national and international. The trust displayed by BNFL managers in the technical, managerial and problem-solving competence capabilities within Romar has facilitated the creation of a number of significant technological collaborations. Their activities permeate the boundaries between firms, drawing expertise from the supply chain and providing opportunities for an exchange of knowledge between supplier firms, and between supplier firms and BNFL (Figure. 4) (Cave *et al*, 2002). Growth has also been made possible by organizational 'administrative innovation' involving the freeing of 'entrepreneurial resources' by alleviating pressures on the two directors caused by managerial diseconomies (Penrose, 1959). Thus, Romar's absorptive capacity (Cohen and Levinthal, 1990) has been re-invigorated by more effective coordination of companies in the supply chain and in doing so they have created relational rents (Dyer and Singh, 1998).

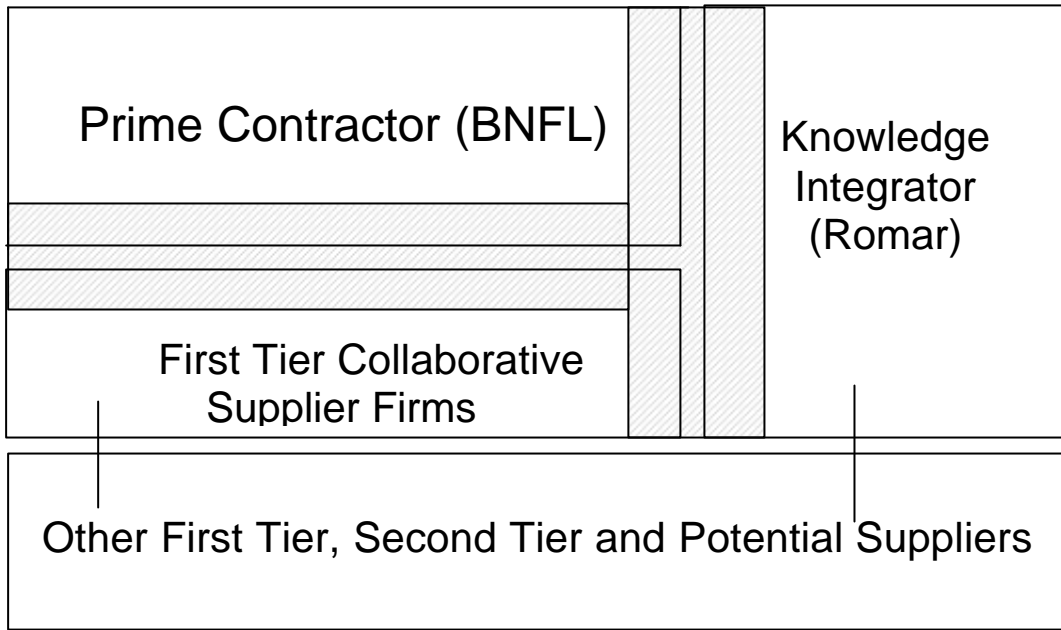


Figure 4. Knowledge Integrator

Romar's innovation activities reflect the distinctive geographic, institutional and industry contexts that have helped shape the company's evolution. Given the unique nature of technological expertise within Romar the case provides an interesting contrast between local embeddedness and a virtual network. In other words, our argument is that Romar directors have utilised a deep understanding of BNFL's activities to become an extremely trusted supplier of essential protective equipment. At the same time, because of their geographic isolation, they have been forced to seek suppliers and collaborators from a very wide geographic area. The networks of interaction that have been crucial to Romar's success are those in the supply chain, where complementary activities created a 'best fit' in social and technical capabilities and provided synergies of knowledge (Cohen and Levinthal, 1990). The supply chain literature emphasises the importance of collaboration founded on trust and mutual obligations between cooperating partners (Corbett *et al*, 1999; Wren *et al*, 1998). There are similarities with the innovation network literature in which 'mutual dependence' (Porter, 1998a) between firms decreases the likelihood of opportunistic behaviour and increases the value of knowledge-sharing. This is related to what Sobrero and Schrader (1998) describe as the distinction between contractual and procedural coordination. In terms of both supply chain relationships and innovation networks there are limits to what can be specified in legal documents and there is a heavy responsibility on those responsible for the day-to-day management of inter-firm relations. In other words, activities associated with procedural coordination are central to the exchange of information between actors in cooperating firms which ensures that all partners benefit from organizational learning. The difference between large firms, which are the focus of the analysis carried out by Sobrero and Schrader (1998), and small firms such as Romar is the same individuals (the owners) are responsible for both contractual and procedural coordination. In large firms, this responsibility is divided between senior managers (contractual) and operational managers (procedural).

As discussed above, key contributors to the innovation network literature such as Saxenian (1994) and Porter (1998a/b) focus on the benefits of regional concentration. Studies of less favoured economies such as Ireland and Wales (Cooke and Morgan, 1998) stress the importance of regional innovation networks. Similarly, Cooke and

Wills (1999) argue that both national and EU programmes are designed to stimulate the development of cooperation between clusters of smaller firms. Even with the benefits of such programmes, some localities lack the fundamental building blocks to allow the formation of entrepreneurial networks or inter-firm relationships evident in sectoral and spatial clusters. In this instance, networking beyond the locality, through global supply chains, provides opportunities to create virtual clusters. The criticality or complexity of the products and the emphasis on innovation in the supply chain creates an impetus for closer collaboration encouraging companies to establish networks of technical expertise beyond their immediate locality. This is certainly the case within Romar as the company is strongly linked to its main customer (BNFL). At the same time, absence of similar technology-based firms in the immediate vicinity has encouraged the creation of a virtual network of suppliers. In fact, the owners have consciously rejected closer ties with local firms because of their perception that such firms lack commitment to innovation and quality central to Romar's competitive advantage. Hence, the lack of similar firms within Cumbria has encouraged the entrepreneurs associated with Romar to create a virtual network that is not constrained by geographic boundaries. As pointed out by Romano *et al* (2001) the emergence of ICTs and associated developments in digital technologies has been an enabler for the emergence of such networks. Equally, the strategic vision of Romar's commercial and technical directors has been an essential element in building a high-technology small firm in a region that has little to offer in terms of support. Consequently, flexibility is needed in policy approach to support small firm networks of innovation that extend beyond the remit of local and central government.

Conclusions

In conclusion, the case of Romar illustrates the potential for smaller firms in isolated regions to succeed given managerial commitment to overcoming the disadvantages of their locality (North and Smallbone, 2000). Growing the business has depended heavily on maintaining good links with their major customer and the only large organization within the region. The fact that BNFL operates in a technological area that demands high levels of quality has provided the entrepreneurial team with opportunities to demonstrate their technical and managerial capabilities. In-house capabilities have been constantly extended by building a virtual network of

companies that operate along the whole of the value chain. This activity has required high levels of trust and entrepreneurial 'risk taking' evident in the actions of Romar's directors to facilitate interactions which allow knowledge transfer and knowledge creation during 'knowledge sharing routines' (Dyer and Singh, 1998; Hakansson, 1987; Nonaka and Takeuchi, 1995). The relationships established through the supply chain have enabled knowledge to be transferred both upstream and downstream creating a virtual cluster of development facilitated through procedural interaction. This case emphasises the importance of managerial and entrepreneurial competence as a source of firm growth (Penrose, 1959). Furthermore, renewal of those competences is possible through entrepreneurial networks that exist wherever procedural interaction occurs.

This single case study does have broader implication for policy, particularly given the propensity for initiatives to create spatial clusters following Porter's (1998a/b) influence. Given the lack of a regional support network, what is striking about this case is that successful innovation was based on managerial capabilities that already existed within the firm. Those internal capabilities were enhanced and extended through relationships with an extended network. Thus, our conclusion is that firms in rural and urban areas can be encouraged to develop these extend networks that will increase their stocks of knowledge and opportunities for growth. However, policy support must be flexible enough to encourage and support inter-regional and international collaborations. Moreover, it is not enough to facilitate procedural interactions that can provide access to knowledge (re-)sources. To make use of that knowledge requires the organizational capability to implement new organizational routines (Nelson and Winter, 1982) to create a stable organizational framework that provides a platform for further innovation (Cantwell, 2002). Thus, policy is required that reaches across borders, but which is linked directly to internal organizational structuring. Policy support for extended entrepreneurial networks within a supply chain structure may provide that opportunity.

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