ROLE PERFORMANCE, NETWORK RESOURCES AND RADICAL INNOVATION

Competitive Paper

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ABSTRACT

The importance of innovation to the creation and renewal of competitive advantage is well recognised and has spawned a wealth of research across diverse knowledge domains such as business and management, technology management, science policy, engineering and operations management. Innovation processes are typically embedded within networks and involve interactions between individual actors within collaborating organisations and allow firms to leverage the functional integration required for success. However, much of the research exploring these issues has focused on incremental innovation and long-term supplier partnerships.

Networks have also been found to be important for the successful development of radical innovations (RI). However, the nature of relational interaction in radical innovation can be quite extreme, as often there are high risks involved, actors lack understanding of each others' working practices, sensitive information must be shared, non-retrievable investments must be made and they are likely to be operating outside their technical comfort zone.

In addition, it is important to highlight that these interactions are not merely activities that firms perform, but are instead a process through which actors, resources and activities are changed and transformed. It is also therefore inevitable that the actors involved will have different identities in each interaction in which they are engaged. The characteristics of each actors 'role performance' will be influenced by the episode of interaction, and is used as a means of separating what happens during the interaction from more general descriptions of what the company is; supplier, customer etc. Neither the research on innovation nor the research on relationships has explicitly explored how these 'role performances' enable firms to access and mobilise relational resources in an environment that explicitly promotes RI. This is an important distinction to make as by amalgamating both role and actor, the nuances of the role itself may be lost, and it becomes axiomatic that particular roles must be performed by particular actors.

This study attempts to capture how external relational resources facilitate the progress from the generation of ideas to eventual market launch of radical innovation through the performance of roles. Empirically, the study is situated within the automotive industry, which is heavily dependent upon radical innovation, and has a network of complex interrelationships, including trade associations and public sector elements. Data were

collected through in-depth interviews with actors playing different roles in the development of several radical innovations.

Nine role performances are identified, including some key relationship facilitation roles, labelled 'Integrating', 'Connecting' and 'Endorsing'. The research also highlights that in situations where there is no prior relational history actors rely on a repertoire of techniques to smooth relational interaction and collaboration, including individual and corporate memory; leveraging personal contacts, mobilising existing relationships, reigniting dormant relationships, and using relationship facilitators.

The paper enhances understanding of important actor role performances, and elaborates upon the important link between these roles and the development phases of RI. In doing so, the paper contributes to an understanding of interaction in inter-organisational networks and outlines the implications for both theory and practice.

Keywords: Radical Innovation, Role Performance, Networks, Resources.

INTRODUCTION

The importance of innovation to the creation and renewal of competitive advantage is well recognised and has spawned a wealth of research across diverse knowledge domains such as business and management, technology management, science policy, engineering and operations management. Innovation processes are typically embedded within networks and involve interactions between collaborating organisations. There are several categorisations of innovativeness (Garcia and Calantone 2002) with a plethora of contemporary terms in operation (Salavou and Avlonitis 2008), many mirroring the 'new to the world' category introduced by Booz Allen Hamilton over 25 years ago. Central to most terminologies is the view that radical innovation (RI) "can consist of advances in component technologies or the highly novel configuration of existing elements" (Siedel 2007; 522) and often disrupts the existing technological (incremental) technological trajectory (Dosi 1982). RI processes require "a search for diverse sources of knowledge, both existing and new, in a manner unfamiliar to those at the centre of this endeavour" (Kelley et al., 2009: 222). It is therefore, very different in process and outcome from incremental innovation which includes refining, improving and/or exploiting an existing technology (Gatignon et al. 2002). The RI process requires persistent and high-level champions (Howell and Higgins 1990) and management systems that cope with the challenge to the current modus operandi. It is characterised by a greater degree of informality, a lack of rules, a greater emphasis on creativity and risk-taking, high levels of communication and cooperation among actors (Song and Swink 2002, Story et al., 2008). Further, the personnel tend to differ from those likely to be involved in more incremental projects, in particularly in terms of their attitudes to risk, their ability to operate without clear lines or responsibility or rules, their informality etc. Moreover, these actors are also likely to be specialists of some kind (Humble and Jones, 1989) who provide particular resources for RI.

There are very specific RI competences (Colarelli O'Connor and DeMartino 2006; Story et al., 2009) that are required at different stages of the development process. Although some large organisations may be capable of mobilising these competences internally (Colarelli O'Connor and DeMartino 2006) through innovation-based corporate entrepreneurship (Kelley et al., 2009) the majority of innovating firms are unlikely to possess all of the necessary capital, knowledge, expertise and technologies internally, and therefore actors integral to an RI project are often located outside of the innovating firm (Story et al., 2009;

Peters et al., 1998). Thus, external actors and relationships are increasingly acknowledged as important to the radical innovation process (e.g Gnyawali and Madhavan, 2001; Pittaway et al., 2004 Powell et al. 2005; Pyka, 2002; Song and Swink 2002), with new relationship investments inevitably required (Story et al., 2009). Despite this, the ability to find and form essential relationships (both internal and external to the innovating organisation) remains a significant obstacle to radical innovation (see Birkinshaw et al., 2007; Story et al., 2007). Researchers are reasonably confident that they understand how relationships operate within fairly stable structures (Anderson and Narus 1990; Gadde and Håkansson, 1994; Gadde and Snehota 2000; Jap 2001; Morgan and Hunt 1995; Wilson 1995), including new product development relationships (Perez and Sanchez, 2003; Sivadas and Dwyer, 2000). However, understanding how relationships work in more complex systems where open structures and processes are involved (Chesbrough, 2003) are less well understood. This context presents a new set of challenges which can inhibit the formation of strong working partnerships throughout the radical innovation process, including a lack of knowledge of firms and their key actors, the absence of history between actors, the need for sharing sensitive information, making non-retrievable investments and intense collaboration before trust has been developed and the fact that they are likely to be working outside their technical comfort zone (Story et al., 2007; Birkinshaw et al., 2007). However, what is certain is that increasing internationalisation, rapid advances in technology, a changing industrial base and increasingly active customers will create even stronger pressures on firms to innovate in the future (Child and Faulkner, 1998; Heikkinen et al., 2007).

Relationships represent access to resources that can be drawn upon, which both influence RI and, are in turn, influenced by the RI process. Through interaction, the resources and activities of individual actors may be combined, exploited, modified or transformed to progress radical innovation. The value of the technology only develops when there is interest from other actors (Ford and Saren, 2001); therefore for the technology to exist it must be accompanied by network mobilization (Easton, 1992). Each actors' activities and resources are heterogeneous and have a different use and value depending on the activities and resources of the other actors with which they are combined (Ford, 2011). Therefore, it is the process by which actors interact that is important. One approach to understanding such interaction is to consider the roles performed by actors during the radical innovation process. Indeed, roles have provided a useful lens to interrogate service encounters (Broderick, 1999), inter-organisational networks (Snow et al., 1992), embeddedness (Montgomery, 1998) and external supply networks (Knight and Harland, 2005). Roles have also proven useful in the context of innovation (Möller et al., 2005) as they "capture the dynamics and diversity of acting in a net (Heikkinen et al., 2007: 921).

A consideration of the roles performed by actors implicitly relies upon the use of a dramaturgical metaphor and explicitly borrows from a role theoretic approach. Indeed, a central premise of role theory is that actors should be viewed as a collection of roles. Roles are socially constructed and evoked by particular situations (Montgomery, 1998). Within the RI process, actors can be understood as enacting particular roles. Roles are clusters of behaviours expected of actors in particular situations (Allen and van de Vliert, 1984). Because RI success is predicated upon the search for diverse knowledge (Kelley et al. 2009) and involves both new technological investments (Hermann, 2009) and new relationship investments (Story et al, 2009) the role scripts are constantly evolving and it is not always obvious which actors are capable of performing particular roles. Some roles may demand a high level of very particular technical expertise or professional knowledge (Humble and Jones, 1989) whereas others may be more dependent upon attitude, professional integrity and perceived trustworthiness.

A number of roles have been identified in previous studies for example those of initiator (Tanner, 1999) broker (Snow et al., 1992) and gatekeeper (Heikkinen et al., 2007). However, there has been a tendency to treat the actor and role as largely synonymous, with, for example, a designer performing a designing role, a broker performing a brokering role and a manufacturer performing a manufacturing role. However, by amalgamating both role and actor, the nuances of the role itself may be lost, and it becomes axiomatic that particular roles must be performed by particular actors. If the assumption is that the funder will always be a venture capitalist, other actors may not audition for that role, or the focal actor may not look beyond the small number of other actors they have 'typecast' in that role. This is akin to assumptions that only Richard Burton can play Lear. While roles may be highly institutionalised with clear expectations and formalised scripts within mature and stable networks, this is unlikely be the case within radical innovations where existing actors have to play unfamiliar roles, new actors are introduced and where new roles are demanded by the particularities of the situation. Thus, improvisation theatre, in which the actors use improvisational acting techniques to perform spontaneously, may be a more appropriate metaphor.

In this paper we interrogate the roles performed by actors involved in radical innovations within the automotive industry. Key actors include component suppliers, automotive manufacturers (OEMs), government agencies, universities, and consultants. The automotive industry has attracted significant research to date, albeit in terms of incremental innovation initiatives such as continuous improvement and direct supply chain linkages (Perez and Sanchez 2003). However, current environmental and legislative drivers demand radical transformations of both the product and processes within this industry. Examples of such drivers include the demands that the industry: effectively tackle recycling and end-of-life challenges; dramatically reduce CO_2 emissions; and deliver traffic management initiatives. The response to these demands involves working with diverse network actors, both inside and outside the traditional supply chain. Thus, the automotive industry is an excellent example of radical innovation in networked firms.

METHODOLOGY

We consider radical innovations that were developed in both the UK and the USA. The unit of analysis is the RI process itself. Empirical data were collected in the UK over a two year period from 2006-2008. The initial phases of data collection involved the identification of innovations of strategic importance to the automotive industry. Through a series of Delphi inspired group discussions (Jolson and Rossow, 1971) key actors to be interviewed were selected. The data presented here are used to interrogate how the actors access and deliver resources through role performances. It is drawn from the wider data set involving actors integral to the development of six radical innovations. All of the innovations are represented in this paper and include an electric vehicle, a fuel cell, an engine management system, emissions reduction technology, oil rings for engine pistons, and direct injection technology. In-depth interviews (Burgess, 1980; Kvale, 1996) were undertaken with senior-level actors including representatives from automotive manufacturing, component suppliers, engineering consultants, trade associations and innovation consultants. Face-to-face interviews allowed iterative discussions of complex topics and thus provided valuable insights into the research issues identified above. Further details on the informants are detailed in appendix 1.

Interviews were informal and contained open-ended questions, allowing informants to explore and describe the role of external relationships during the development process for the innovations under investigation. A general flexible topic guide, driven by extant research on

RI, on relationships and networks, as well as more focused studies of the automotive industry, was produced at the outset (Merton et al., 1990; Seidman, 1991). Data collection and analysis involved an iterative process, which allowed issues that emerged organically in earlier interviews to be added to the schedule for subsequent interviews. Thus, these guides were organic, developing and altering as interesting issues emerged and insights were uncovered. Each interview lasted approximately 1½ hours, although occasionally that time was exceeded where informants raised unforeseen issues. Interview data was supplemented with firm documentation and written communications, and, where necessary short telephone interviews, where additional clarification was required.

An initial review of the data captured the broad themes of concern to informants, with subsequent analysis intended to extrapolate extensive verbatim quotations from informants. Data analysis followed a form of transcript based analysis using axial coding. Given the extent to which the data were embedded in the context of each of the radical innovations coding and interrogation was carried out by the authors. Emphasis was placed on allowing the actors to describe and explain their experiences of RI using their own language and jargon. By allowing these expert informants to describe their experiences, a clearer picture emerged of how network resources develop RI competences. Thus, we include extensive verbatim quotations that are representative and illustrative of the roles played by actors in the network in delivering resources. In particular, the data suggest that particular network roles are important at particular points in time.

ACTORS, RESOURCES AND ROLES

All of the innovations studied were the result of external interactions and collaborations between firms in the network.

The resources available in the network include technical, organisational and knowledge resources and are accessed through relationships between key actors. Of particular importance is that resources are provided by actors within the network through their performance of key roles. Importantly, while several actors may have the resources needed, it is through interaction and execution of specific roles that such resources are accessed. Perhaps, of even greater importance is that individual resources may be insufficient to progress a radical idea through the various stages necessary to develop and launch a successful RI. Therefore, this study outlines how interaction within the network and the performing of various roles provide the necessary competences to develop a successful RI.

This research attempted to establish how different actors perform roles necessary to progress a radical innovation. However, as has also been identified by Heikkinen and colleagues (2007), this proved exceedingly complex as it appears that different actors may enact different roles at various stages of the development of the innovation. For example, the discovery phase could involve component suppliers, automotive manufacturers, government agencies, universities, and consultants. The incubation phase, where the radical idea is further developed into a business proposal, appeared to be supported and nourished by actors outside the traditional supply chain, including government agencies, as well as the usual component suppliers and automotive manufacturers. During the developmental phase different roles were required to assimilate the innovation into the relevant sub-system and to progress to full product development and testing. This involves working with an often complex range of suppliers, technology specialists and sometimes includes potential customers (usually OEMs). The commercialisation phase is concerned with final market launch and is focused on ensuring production and supply capability, marketing and sales. This phase highlighted the importance of a market-facing facilitating role that helps to speed up the diffusion of the

innovation into the marketplace. All four phases share a common goal of mobilising resources in an environment characterised by extremely high levels of uncertainty. These resources are best accessed and activated through effective relationships between actors and this study attempts to delineate how the necessary roles to develop these resources are enacted among actors within the network.

ROLES

The data detail and explicate the roles played by external partnerships in supporting these capabilities. What emerges is that it may be necessary for several actors to collaborate to effectively perform a single role. In other cases, one actor may be capable of performing several different roles:

> *"For example, the NGO has several roles. It has a role as a funding mechanism, it has a role as a procurer, and it has a role as a tester, an evaluator of not just product X in particular, but electric vehicles in general. Because we are more interested in how people interact with electric vehicles generally, whether electric vehicles are capable of filling the gap that would otherwise have been filled by a car with an internal combustion engine… So, we have a number of roles and to some extent provide a PR role as well" [Informant 5, NGO]*

This excerpt demonstrates how a single actor performs a number of very different roles, including funding, procuring, testing, evaluating and marketing. These roles can be clearly linked to the provision of financial, technical and knowledge resources. Although informants use the term 'role' very loosely, our interpretation is that nine clear roles emerge which advance understanding of how resources are accessed for RI by actors. Following Heikkinen et al., (2007) we distinguish between task-oriented roles – articulating, funding, developing, prototyping and producing – and network-oriented roles – connecting, integrating and endorsing. All of these roles are not necessarily enacted for each innovation, and several roles may be played by individual actors (Anderson et al., 1998; Heikkinen et al., 2007). What is important is not which actor plays the role, but rather, that, where necessary, the role is performed by actors within the network. What is also important is when these roles are played as there is some evidence to suggest that actors may be required to perform different roles in different phases of the development process (Heikkinen et al., 2007).

Task-Oriented Role Performances

Articulating

Articulating is the process of taking the initial idea and developing a comprehensive description of the full concept, and the actors involved tend to be initiators of the development. Indeed, many of the actors who performed this role were component suppliers.

> *"The original idea came from one of our staff. We then did a huge amount of work looking at all sorts of different designs. We did our own initial, our own brainstorming and came up with all different sorts of styles" (Informant 14, traditional component supplier].*

Here the radical oil ring idea was articulated by the component supplier as a result of market research they had undertaken. In another case, a component supplier and an OEM, who had been working on an idea simultaneously, discussed their idea at a networking event. As a result, they identified the potential to collaborate in performing the articulating role. The

OEM had been struggled because it lacked the necessary competences and resources to reach a viable solution. However, by inviting the component supplier to work with them on the project, the OEM was able to access resources necessary to complete the discovery phase. This demonstrates that different actors may individually enact particular role performances (in this case articulating the idea) but that collaboration between actors may also be necessary to convert their combined resources (technical resources, market resources, knowledge resources) into a workable discovery to complete the phase.

> *"We'd got a little bit of work going on electric vehicles and then just I suppose by chance – but I mean, one of GM's senior Technical Managers at the time, who was looking at control system solutions had got a project just arrived on his desk effectively to look at a hybrid version of their large pick-up trucks. And he was looking for potential suppliers to work on developing the solution. And he was fairly tight on resource in terms of engineers anyway within his controls group. And they'd done a bit of work with [large component supplier] on the motor in terms of the stop/start system. So they'd got some information but they needed to take it forward into production. So he was quite intrigued by the work that we'd done, our knowledge on engine controls and what we were doing on electric vehicles and the hybrid was sort of somewhere in between. And asked us if we were interested in looking at some of his problems." (Informant 10, New component supplier).*

While in this case, the component supplier intended to ultimately develop and supply this product, other actors performing the articulating role do not see themselves having a role to perform beyond developing the initial idea:

> *"We want to have a mixed portfolio of potential applications because we're not going to do mass production, for example, if we were working with a big [OEM] then we would license the technology to them, then they would move and do the mass production. So we can go into lots of different sectors because we are only doing the licensing deal". [Informant 4, New component supplier].*

The articulating role is only performed during the discovery phase. Various actors may play this role including OEMs and component suppliers. A single actor may fulfil the requirements of the role if that actor has all of the necessary resource in-house. Where these resources are dispersed within the network, interaction and collaboration between actors is necessary to fully mobilise the resources necessary to complete the discovery phase. Once the radical idea has been discovered, competences for the incubation phase are necessary to move the innovation forward. Here the Funding role comes into play, as explained below.

Funding

The incubation phase requires the ability to access the necessary financial resources to support the development of a radical idea into a well developed business case, even to the point of generating prototypes. Because the technology involved is novel and the marketplace is likely to be under-defined, significant amounts of research and development are required to develop a business case. Thus, the performance of the funding role is essential to incubating the project. The tradition within the automotive industry is that RI projects tend to be funded by the OEMs. However, as the marketplace has become more competitive, automotive manufacturers are operating within tighter budgetary restrictions and they have allocated less and less funds to more radical innovations. However, they continue to play a supporting role, as actors tend to be more confident funding innovations where the manufacturer is involved, as this is regarded as a barometer for the potentiality and ultimate viability of the innovation.

"Very often the larger company, if they're playing some sort of executive role in the project, they might actually not charge any monies to the project, so they're just keeping a watching eye, because it's very easy, particularly in academia, to lose sight of the overall objective. You get a nice bit of interesting research work and you're off down there and you need the end user ….. the people working on the project might say, 'It's only going to be another 10 pence, that'll be okay' and the end user will say, 'Come on, we're actually looking at 0.1 of a pence here. Get back to your research work and do it again.'" (Informant 9, Trade association).

Because of the high risks involved and the lack of ability to do market assessments, finding the necessary actors who are capable of performing the funding role can be one of the biggest barriers to getting the project past the discovery stage.

"One of the major challenges for us was getting enough funds all in one place to actually do all the trials we needed to do" (Informant 12, Engineering designer)

The innovating firm may perform the funding role itself through accessing internal funds or by borrowing. They may also try to entice venture capitalists to perform this role.

"We are putting a hell of a lot of money in ourselves, and we are getting a reasonable amount of money from the Technology Strategy Board" (Informant 4, New component supplier]

In the UK there is evidence that government increasingly perform a funding role through Technology Strategy Board, the Regional development agency's (RDAs) or the Research councils. Government has also introduced legislation and mandates for local councils demanding that they find innovative solutions to delivering services which acts as a pull mechanism from the marketplace, making it easier to find companies willing to perform the funding role.

"The idea [need for] of government funding is where you wouldn't normally make a business plan and be able to progress. So if you were running a business and you said, 'I need to develop such and such a process', you would normally expect to raise the money yourself or go and get some venture capitalists or something like this. The idea of the public purse is where there is a serious risk element. You don't know whether the technology works so how can you get somebody to invest when you don't even know the technology is there?" (Informant 9, Trade association)

It appears that government is needed to perform the funding role when other actors are deterred because of the high risks and unclear returns that are associated with more radical ideas. Actors may not be confident that the idea can be incubated to produce a testable prototype. Another informant had hoped that the funding role would be performed jointly by government funding and a beta test firm. However, because the trials for this product had to be set-up abroad, the government were unable to perform the funding role. As a result, the informant had to find a partner that was capable of performing both the funding role and the developing role. Finding actors who were willing and able to perform both roles was problematic and resulted in a much longer development time.

Given the high stakes involved and the large financing required, the ability to source and access financial resources is particularly important. It is often necessary for the innovating firm to already have a strong profile in order to persuade other actors to perform the funding role, or to develop such a profile relatively quickly. Upgrading such non-monetary resources, like status, is important for younger, smaller firms (Podolny et al., 1996; Stuart et al., 1999). Thus, the ability to mobilise marketing resources is also important.

"We were developing an X idea and we wanted to get PR value from it. It improves the value of the company by having a higher profile. People know the company so when it comes time to invest, they think 'that's the company that has the X'. It's in the back of their mind - so it's all part of managing the company's profile" [Informant 4, New component supplier].

Whereas in the past OEMs would have been the main performers of the funding role, it is increasingly evident that other actors (e.g. venture capitalists, banks, government) individually or collectively are now necessary to perform this role.

Developing

Operand resources including technical expertise and knowledge are essential to progressing through the incubation, acceleration and commercialisation phases in radical innovations. In the example below, the developing role was co-performed with the principle part played by large component supplier supported by a smaller component supplier (see Knudsen 2007).

"They were struggling for resource at [large tier 1 component supplier] who made the [system] to develop the algorithms, the unique algorithms, for the new engine, because of it being so different. So, they opened up their system and gave us access to their system and we developed and wrote the prototype algorithms and fed them through to them to productionise the software. So it limited the amount of work they had to do with their resources. All they had to do was check that they were happy with the module and that it integrated into the software okay and then they put it through to production, so it worked very well." (Informant 10, New component supplier).

In this case, the principle actor did not have the necessary resources to effectively perform the role and needed to access the complementary (Knudsen, 2007) resources of another actor. The process of acting and interacting transforms the resources to fulfil the task (developing the idea) as well as transforming the actors themselves through the acquisition of new knowledge and technical resources (McEvily and Zaheer, 1999).

"But this [interaction with the large tier 1 component supplier] gave us access to the unique algorithms for the [system] and the fact that we were doing our own unique algorithms within the [related system] as well, and interfacing with [component supplier] who were the developers and manufacturers of the electric machine that became the stop/start system on the product. …. If you don't do it, you don't learn about the problems so you can't feed that into your next generation product" (Informant 10, New component supplier).

The new knowledge and technical resources acquired thorough interaction and role performance inevitably enhance the profile of the actors and their subsequent ability to attract new ties (Powell et al 1996):

"…It was a learning exercise at two levels, one was the process of working in such an environment [on a government funded project] and the other was intellectual property/know-how that we gained through the development; one of the objectives that we wanted to achieve was to create …. systems that could be used for future engines." (Informant 6, Sub-component developer).

Opportunities to work closely with another actor in performing the developing role also influence the actors' future behaviour. Specifically, intense communication creates bonds which impact the developing relationship and can bring actors closer together.

"company X (developer) have been really good to us since we agreed to be a tester of the product – we are now borrowing [their product] for a number of events free of

charge – they said 'give it a real test so that we can do comparisons with [the traditional product]" (Informant 3, City Council).

Potential customers may also provide important resources to enable actors to perform the developing role effectively:

"Sometimes you can sell them [radical ideas] to a customer very early on, almost before they're complete as a product. So in other words you will try to get a customer involved in an early stage of development. If you think this is a product that's really going to suit them and it's a customer you're very close with and do a lot of business with, you might say look, could we have your engine to test this product on? You provide us the engine; we'll do all the rest and well share the results with you. And the results are good, to some degree, it's already sold because he's got all that advantage on his engine, he knows how good it is, etc." [Informant 14, traditional component supplier]

Prototyping

Within the automotive industry this role can be performed by a number of actors including engineering consultants, who only work up to the prototype phase of development, through to large manufacturing suppliers who have in-house capabilities to develop prototypes themselves. Essentially, a great deal depends upon whether actors have all the technical, knowledge and financial resources to engage with the project at this level. Indeed, the findings of this study suggest that actors can have core and peripheral prototyping roles for RI. For example, in this study, many of the large engineering consultants didn't have the resources, capabilities and specialist cast required in-house to fully develop the innovations. As a result, other actors were required to undertake prototyping of sections/sub-systems of the innovation. Thus, for very radical innovations, multiple specialist actors are required to effectively perform the prototyping role. Although Heikkinen et al., (2007) refer to these actors as playing an 'auxiliary' role, we argue that because their performance is essential to fulfilling the prototyping role, it is the actors and not the role they play that should be understood as auxiliary.

"Our part of the project if you like was to open the engine control system and then to collaborate with [Main Prototyper 1] in the development of bespoke control strategies to allow them to realise the control of the mechanical concept". (Informant 6, Sub-component developer).

Often these auxiliary actors are required to really stretch their capabilities in performing their role. This occurs because not only is it a stretch of their technical abilities but also because for radical innovations the role script is often unclear and is evolving in concert with the performance of other actors. As such, this is an excellent example of where actors are required to improvise rather than simply enact a defined role.

Producing

Many of the actors who perform the developing and prototyping roles do not have the capabilities and expertise to perform the producing role and therefore new actors with more specialised capabilities are required. Given the scale of production and the associated costs, the actors chosen to perform this role often already have a reputation for producing quality goods.

"We'd design the systems and had other companies make them. So we did the design and then the manufacture was done by all sorts of people really. …. So we would design it, develop it, do the engineering validation of the design. Then we would sub-contract the production - they'd do the production. Which worked very well. Because the end customer was happy with the production environment and the quality associated with the production environment because these people were manufacturing similar products to similar customers to very high quality level. So they were confident that they were going to get a good product at the end of the day". (Informant 10, New component supplier).

Network-oriented Role Performances

Connecting

The connecting role is similar to a brokering role in that actors playing the role bring other actors together who have the right technical know-how to develop and complete a project (Snow et al., 1992). However, unlike brokers, who tend to be described as 'calculating and politically savvy operators' (Burt, 1992), the data emphasise that actors playing the connecting role do more than just bring actors together for monetary gain. They also facilitate the forming and performing of these new connections. This encapsulates the ideas presented regarding boundary spanning roles described by Aiken and colleagues (1980) and Tushman (1977) who are described as "well respected guardians who redirect crucial information" (Tushman, 1977), but also emphasises the on-going nature of this role performance. The role of connecting may be important for all four phases of the development process: discovery, incubation, acceleration and commercialisation. The role is essential for understanding which resources exist within the network, bringing various actors together, as well as in supporting and nourishing embryonic partnerships. Some actors perform the connecting role themselves. Individual and corporate memory is particularly important as is the history of interaction between actors and the personal contacts and social resources that they hold:

"It's not purely coincidence that [local City Council] has ended up working with [NGO], there is a certain history to it, that goes back to X's [actor at NGO] air quality days and the relationship that [we] had with [X's old company] at that time and the personal relationship that I had with X and various other people that he's introduced me to since then, it's something that evolves really and progresses" (Informant 2, City Council).

While some actors within the network perform this role informally or inadvertently, other actors intentionally develop and promote their reputation in connecting. Industry associations are particularly adept at performing the connecting role:

"Guys will come to us with like, 'it would be really nice to do this but the technology doesn't exist, does it, and we haven't got a research organisation to do it.' And I say, 'Ah yeah, but I know a university down the road that does." (Informant 9, Trade association).

Participation in exhibitions allows actors to showcase their own expertise as well as providing opportunities for finding partners that can perform specialised roles:

"It was an exhibition in California where [the US army] saw the information that [new component supplier] were displaying and said, oh we'd like to do some tests on that and it started from there" (Informant 12, Engineering designer).

"On one of the stands we had at the SAE show we were demonstrating some of our early work [on the new product] because the Chairman felt that, although it was early days, this was an important area for us because we had gained some important experience in this area for the future ….. and we were looking in the States for a market for it, you know, 100 here, 200 there, because it's such a big market out there" (Informant 10, New component supplier)

Actors performing the connecting role generate the contacts that they require through networking at events or membership of particular societies etc. The performance of this role is particularly important for radical innovation because the firms involved don't automatically know where they might find partners who have the capabilities they require.

"We found that most of our clients come through networking. We have extensive networks that were built up over the years. We're members of the licensing executive society. I'm a full member of the Chartered Institute of Managers. The company is a member of the Environmental Industries Group. We act as mentors for NESTA, and we also advise for Business Links – we are their specialist IP advisors. So we have extensive networks. And from our networks is generally where we find people are referred to us or they find out about us from people - their patent agents, their lawyers, friends of friends" (Informant 13, Innovation consultant).

As illustrated here, performing the connecting role enables actors to identify who has the necessary resources, and provides opportunities for them to communicate and potentially work together. As a result, focused networking events are regarded as being particularly important.

"Quite a lot of suppliers like [trade association event] because that means they get actually introduced into the OEM or the smaller supplier gets introduced to a larger supplier. So they actually use it and can often then strike up relationships outside of the particular project." (Informant 9, Trade association).

However, connecting is more than just providing opportunities for actors to meet. It goes beyond this and includes actively encouraging and supporting interactions between actors.

"I think if you sit back and expect people to do things, they won't and a good illustration of that would be with this project, without our involvement and without a certain amount of pushing the issue and a certain amount of having regard to the new [government] targets, your traditional fleet manager would've probably been reluctant to take on these things" (Informant 2, City Council).

Thus, the role of connecting is important, not only as a means for introducing potential partners but also by helping these relationships to develop. The actors who specialise in the connecting role rely a great deal upon their reputation, their extensive network of contacts, and their ability to smooth the relationship development process, exhibiting therefore, a high level of social and performance capital.

"It [personal contact] allows you to get into places where you wouldn't necessarily get if you went into the front door. It gives you the visitors' pass. And people say, oh yes, I know her. She's trustworthy. (Informant 13, Innovation consultant).

The connecting role is particularly important in providing opportunities to access and convert network resources during the incubation and development phases of the RI. Although a great deal of connecting may be informal, in recognition of its centrality, we are increasingly seeing consulting firms who specialise in this role. For example, one consultancy firm is described as specialising:

"In assisting innovators and SMEs to protect, value and then commercialise their new technology". (Informant 13, Innovation consultant).

Integrating

Actors performing an integrating role are also necessary for the successful development of radical new products. Although the role tends to be described almost as a project champion role, actors performing the role seem to have a much broader remit in terms of co-ordination responsibilities, mostly due to the larger networks involved. As such, while some aspects of the role performance are similar to that of connecting, actors performing the integrating role are more technically involved in designating and co-ordinating tasks and responsibilities, setting targets, and overseeing progress. One actor who has performed the integrating role describes it as follows:

"We did most of the integration work. It was great to be part of that and we gained an awful lot of knowledge about the system. …. It is important that the system is fully integrated within the vehicle, but in order to do it you've got to get closer to your system suppliers. ….. We felt that our future was more in systems integration and understanding the interaction of these systems." (Informant 10, New component supplier).

The effective performance of the integrating role is essential given that many components within cars are part of bigger systems – where all the elements need to work together. Again, a number of actors can and do perform this role for radical innovations. In the excerpt below a component supplier describes how a key contact in the engineering consultancy performed this role.

"I'd say [X] would be best described as the lead technical person who brought together the technical concept of the engine, so whilst he wouldn't necessarily do the individual detailed design of any one part, it's his engine and so he brought together the design, he cajoled people to try to get the best result, technically and he's the kind of figurehead of the project, technical figurehead and leader" (Informant 6, Sub-component developer).

The performance of the integrating role is extremely important during the main development phase, monitoring the development of various component prototypes and ensuring their ultimate integration into the RI. Actors performing the integrating role simultaneously contribute to the performance of the connecting role.

Endorsing

This is a particular facilitation role played by a few actors, and it specifically deals with the market function. The actors performing an endorsing role specifically contribute to market-making for the radical innovation. There are strong similarities with the connecting role as one aspect includes supporting relationships between actors. However, actors performing an endorsing role are solely focused on the marketplace with the intention of encouraging new product trial. As such, endorsing is essential to mobilise the resources necessary to commercialise the RI:

"I think if you sit back and expect people to do things, they won't and a good illustration of that would be with this project, without our involvement and without a certain amount of pushing the issue and a certain amount of having regard to the new

[government] targets, your traditional fleet manager would've probably been reluctant to take on these things" (Informant 2, City Council).

Many of the actors who perform an endorsing role leverage their personal and professional relationships and use their own professional judgment as a signal of the trustworthiness and competence of other actors:

"I know the people [at the component supplier], I have confidence in them and because I have confidence in them I'm able to go to people like the owners of [aftermarket car accessory producer], and say with confidence this is the technology for them, meet with the guys from [the component supplier] and see what you think, let's develop a relationship, and it's through the confidence of knowing them personality that I can do that" (Informant 12, Engineering designer).

Actors who are able to perform the endorsing role may be actively recruited to a project by lead companies to help speed up the market introduction of their product.

"We had a direct approach from the project manager of a [well established OEM] to [NGO] saying would we like to be involved in the Programme. It fitted our objectives and so we said yes and have since put a reasonable amount of funding into the Programme, to be shared amongst the partners to effectively subsidise each trial. We have also helped the project management people [at the OEM] to find a home for a reasonable number of the 100 trial products and have even purchased four vehicles, either for our own use or to be used in conjunction with other organisations for learning purposes" (Informant 5, NGO)

The informant below describes how he performed the endorsing role for an NGO thereby expanding their market facing network:

"So we've been able to introduce [NGO] to various people in [local city] that we've come across and vice versa - you know we got them together with the Community Transport people, the people running the fleet, and with [local shopping centre]. You know we've already got those networks, so when you get to know what [NGO's] objectives are, you realise that they're not a million miles away from our objectives and that we can make use of existing networks to the benefit of [NGO] in the same way we use them for ourselves. I suppose our networks tend to be – well as you'd expect local or regional, whereas [NGO's] tend to be national." (Informant 2, City Council).

There is also evidence of interaction between the actors performing the technology 'connecting' role and the actors performing these market facing 'endorsing' roles.

"We work together very closely because we actually see [NGO] carrying on our technology and helping to arrange for demonstrators and exploiting the technology. So it's [NGO] that should actually be working out how to persuade people to produce, exploit, finance [the product]". (Informant 9, Trade association)

However, it also appears that actors performing this role are not specifically involved in the management of the radical innovation, only in helping to get it to market, which can be a problem for them if any technical problems arise that lead the product to being late to market.

"We've got a limited amount of influence in the Programme ….. [NGO] is not the Project Manager in the conventional sense of the word, because we're not in direct contact with the supply chain. You can only be the Project Manager if you are in a position to actually cause something to change, and we're not directly in there. You

can't barge into somebody else's Company and tell them how to do those jobs". (Informant 5, NGO)

This quotation serves to demonstrate that although there are fuzzy boundaries between various role performances, each role does have clear responsibilities. Thus, in this example, we see how *integrating* differs from *endorsing* in that actors performing the integrating role have clearer project management responsibilities. Similarly, the role of *connecting* differs from *endorsing* in that the connecting role requires the ability to bring together actors on the supply side – ensuring the development of the innovation, whereas the role of *endorsing* is focused on the ability to operate as market creators. Thus, the performance of the *endorsing* role is often to gain exposure for the innovation, and thus their marketing and promotion resources are particularly important for aiding the RI through the commercialisation phase.

"[Their involvement in the project] fits in best for its PR value – you could even say it's propaganda, and we've got involved with X, the shopping centre around the corner to put in some necessary infrastructure that can be used free of charge" (Informant 2, City Council).

The Role Played by the Customer

One role that has not been fore-grounded in many previous studies is that of the user of the innovation. In many previous studies the innovations were initiated by the end manufacturer of the innovation being developed, who are therefore seen as the customer, and no assessment is provided of end user involvement. However, examining who performs the customer role and how it is performed is important.

The data shows that the performance of the customer role is actually very complex and throughout the development of an innovation can be played by several diverse actors:

"There's been three phases of the project, there was a first simulation only phase, which was done with X [large OEM], then there was the engine, first engine demo, which is the project that we became involved with, which is when they need an [system] because we actually had to run an engine rather than just simulate it and that phase [X] (large OEM) didn't choose to be involved but [Y](smaller OEM) gave this sort of, 'we're going to be involved' and then gave it very little support [because of an argued conflict of interest with another research project they were involved with], the customer over this phase of the project was arguably the government (the main funder of the project), and now it's planned to move to the third phase which is to build a demonstration vehicle which again [Y] are committed to support" (Informant 6, Sub-component developer).

The expectations regarding OEM's getting on board with RIs is that they use the demonstration phase to decide whether the project can deliver, or:

"whether it is just another 'interesting concept' (Informant 6, Sub-component developer),

and whether end users will be interested in the benefits it offers:

"whether customers [in the trials] demand it" (Informant 12, Engineering designer).

Evidence of different actors playing a customer role is evident throughout the interviews. In another example, the component supplier below demonstrates how customers for the radical

innovation they were involved with was limited, because many of the larger OEMs were themselves involved in similar developments.

> *"We try to have a portfolio of customers … in automotive there isn't actually that many major OEMs so you have to work with who you can. Most of them have already got their own programmes in this area so hence the reason we targeted X [smaller OEM] because they weren't developing their own version – so we thought we'd got a chance" (Informant 4, New component supplier).*

In this regard, potential customers may also be potential competitors.

Role Performances Deliver Competences

Although the roles have been presented here as distinctive, it is clear that the boundaries between roles can become fuzzy, particularly when several roles are performed by a single actor. One informant described the problems that can arise when roles become blurred. In this case, the organisation attempted to develop competences itself because of the difficulties of sourcing such competences from other actors within the network. However, this became:

> *"a big additional challenge for the project" that led to conflict and ultimately problems with the final solution at the incubation stage "the engine never ran with the intended compression ratio" (Informant 6, Sub-component developer).*

What is also clear from the case studies examined is that actors don't have the luxury of taking small incremental steps towards relationship building and instead have to rely on a repertoire of techniques to smooth relational interaction and collaboration. These include mobilising existing relationships, reigniting dormant relationships, leveraging personal contacts and using relationship facilitators (actors performing connecting and endorsing roles). For example, some actors clearly have a long term view of their relationships and how they can better facilitate the innovation process. Some actors may rely upon existing relationship and others may intentionally cultivate relationships with particular actors that might prove beneficial in the future:

> *"My predecessor took the decision that we should form effectively unofficial strategic alliance with X …. so, we built up a relationship with X, and so it was natural that when [they] were looking for a[n] [component] supplier to collaborate with them … where they wanted an unprecedented level of access … that we would be the people they would talk to, because of the relationship that we were building up in other areas" (Informant 6, Component supplier)*

The following extracts shows how relationships can be reignited when needed and the value of personal contacts.

> *"It's not purely coincidence that [local City Council] has ended up working with [NGO], there is a certain history to it, that goes back to [actor at NGO] air quality days and the relationship that [we] had with [his old company] at that time and the personal relationship that I had with [him] and various other people that he's introduced me to since then, it's something that evolves really and progresses" (Informant 2, City Council).*

> *"[personal contact] allows you to get into places where you wouldn't necessarily get if you went to the front door. It gives you the visitors' pass. And people say, oh yes, I know her. She's trustworthy. (Informant 13, Innovation consultant).*

The identification of key role performances in the process of radical innovation enhances our understanding of how and where external relationships and networks provide support for radical innovations. It is particularly insightful to map the different roles of internal and external relationships in terms of when they are performed during the four key phases of development. For example, it is obvious that the discovery phase is supported by articulating, funding and, to a lesser extent, connecting role performances. While all three role performances continue to be important during the incubation phase, they are likely to be insufficient on their own and thus, the performance of integrating and prototyping roles become fore grounded. The acceleration phase is supported primarily by developing, prototyping, producing, connecting and integrating role performances, with additional input from customers, and actors performing endorsing roles. Producing, and endorsing roles are the primary roles performed during the commercialisation phase, with continued, but less central support from other actors. We also observe a much stronger interaction with end customers during these last two phases, once the innovation is better developed. Thus, during the often extensive lead time from idea generation to market offering, different phases are supported and the necessary competences mobilised by a variety of network actors, some of whom may only contribute resources and capabilities that are important for a relatively short period of time. Also interesting is that some roles require some capability in several competences, for example integrating and connecting. While there is research on the network role of integrators (Lawrence and Lorsch 1967; Vilkinas and Cartan, 2001) also termed *liaisons* (Mintzberg, 1980; Tushman, 1977), or *new venture creation champions* (Gupta et al., 2006), the connecting and endorsing roles are ones that are less understood, but, as evidenced from the marketplace, are roles that are becoming increasingly important and are offering organisations a clear competitive advantage through the filling of structural holes (Arya and Lin, 2007; Gnyawali and Madhavan, 2001). Given that a number of these roles were performed by specialist consultants, this suggests a need to further research the role consultants play in the innovation process. In line with Knudsen (2007) our data supports the idea that some consultants can perform task-oriented roles, providing technical knowledge, acting as an additional workforce or advising on the process. However, in contrast, our data also highlights the potential of consultants to perform key facilitating roles, particularly the connecting role. In filling structural holes in the network through their ability to perform these roles successfully they are seen to be carving out a clear, defendable competitive advantage for themselves (Arya and Lin, 2007Gnyawali and Madhavan, 2001).

End customers of these radical innovations tend to be OEMs. As previously outlined, they may perform several roles within the RI process, occasionally acting as originators or funders, often needed to match against the funding provided by the Government through the research councils. They may also play an important role as endorsers of the RI, by highlighting the potential value of the innovation to the development of their products or processes.

It is also interesting to note that a customer is not essential in the process of radical innovations. Indeed, because of the level of risk involved, the need for secrecy and the necessity of maintaining credibility, customers may be excluded from the process until the product is ready for testing. This is because industry proponents recognise that they cannot always deliver on the radical idea.

> *"I wanted a safe environment; I didn't want to develop a [system] on what I would call a live project with an OEM" (Informant 6, Sub-component developer).*

As a result, failure to deliver may impact upon their reputation in the marketplace and subsequently affect their perceived trustworthiness on other projects and by other potential partners (Harris et al., 2003).

The data highlights the complexity and diversity of the network actors essential to realising a radically new product. For all the case studies presented, these relationships are essential to the process of developing a radical innovation. However, the actor involvement is not steady over the period of the development. While some relationships do develop between actors and remain central over the period of the development, others are only intensely involved for a very short time. This is particularly true for engineering consultants, whose role may only extend to the incubation phase, and some sub-system prototypers, who can be involved solely in the acceleration phase.

Moreover, the roles they play in the innovation also differ significantly, as do their interaction processes. Some actors play a number of roles, and the focus of each role changes during the course of the radical innovation (Heikkinen et al., 2007). Thus, what emerges is that, in contrast to received wisdom (Dwyer et al., 1987) relationships do not necessarily develop incrementally over time and display increasing intensity and greater levels of trust and commitment. Rather, what emerges is that not only do individual relationships develop in more erratic movements of increasing and decreasing intensity (Hedaa, 1993) but, also, that the network of relationships offers a resource where by different relationships contribute to particular competences at significant points in time and then appear to end. It is likely, however, that these relationships are simply dormant, and that the investment in that relationship will allow it to become reignited at another point in time when access to particular resources are again necessary, either for this or another radical innovation. This is in line with the research on interimistic relational exchange (Lambe et al., 2000).

CONCLUSIONS

It is increasingly evident that within-firm competences are unlikely to be sufficient for the development of radical innovations; particularly those that are part of a complex product made up of hierarchically ordered sub-systems (Gatignon et al., 2002), as is the case of innovations in a number of industries, like aerospace and automotive. This is because the necessary resources are widely dispersed within the network and can only be accessed through interaction. Moreover, the degree to which resources can be converted into competences for RI seems to be closely related to how well individual actors perform the necessary roles.

This research also contributes to the understanding of the role of external relationships in supporting and sustaining the competences necessary to develop successful RIs. It highlights that few (if any) firms are likely to have the competences to undertake all four phases in-house. Indeed, despite highlighting the centrality of certain roles for radical innovation, the study also acknowledges that certain roles are only valuable for a very short time period. Rather than investing in developing competences internally, investment in relationships and networks is a more sustainable business model for many firms. The study delineates the roles performed by key protagonists during the development of radical new products and demonstrates how these interactions contribute to the different phases of the development process. This highlights that further research into how relationships can be developed and managed in a dynamic environment needs greater attention. In particular, organisations need to understand how to invest in diverse relationships, how to mobilise dormant relationships as and when the need arises and how to mobilise the resources of consultants and government bodies to access resources for radical innovation that exist outside their organisation.

Relationship facilitators (O'Malley and Ryan, 2006), in this case government agencies and consultants offers a great deal of potentiality and is deserving of far greater attention by both academics and practitioners.

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Appendix 1

Table 1: Organisations, Technologies and Informants.

Focal Case	Technological Innovation	Informant (Informant ID number)	Organisation
A	Electric Vehicle	Academic (1)	University
A	Electric Vehicle	Environment Strategy Development Manager (2)	City Council
A	Electric vehicle	Environmental manager (3)	City Council
B	Fuel Cell	Director of Research and Technology (4)	New component supplier
B	Fuel Cell/ Low Carbon	Operations manager (5)	NGO
C	Engine management system	Senior manager (6)	Sub-component developer
C	Engine management system	Professor (7)	University
C	Engine management system	Chief Engineer (8)	Engineering Consultancy
C	Engine management system	Programme manager (9)	Trade association
C	Engine management system	Company Director (10)	New component supplier
C	Engine management system	Director (11)	Traditional component supplier
D	Emissions reduction for Heavy goods vehicles	Engineering manager (12)	Engineering designer
D	Emissions reduction for heavy goods vehicles	Director (13)	Innovation consultant
E	New oil rings for automotive engine pistons	Chief Engineer (14)	Traditional Component Supplier
F	Direct Injection technology for automotive engine	Senior Manager (15)	OEM