The evolution of an aerospace innovation network: a ten-year case study

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ABSTRACT

This paper examines radical change in the market positioning and associated capabilities of an Australian Aerospace company through the 1990's that lead to the development of an innovation network. The paper gives some background to the position of the company, briefly discusses supply chain relationships and describes the evolution of a collaborative R&D approach to innovative product and process development in a business environment where there may be significant discontinuities between projects. Project factors were the need for fast-tracked development, integration with a customer product development program and the management of multiple risk factors. A transaction oriented network model approach is used to characterize some of the actor and environment contingent outcomes observed.

INTRODUCTION

A case study describes the evolution of network practices over a number of years, rather than presenting a snapshot of a network at some point in time. Strategies adopted by the case study company's customers and suppliers impacted upon its position in the supply chain and strategies adopted by the company in response, conditioned the environment for the development of a particular kind of business network. This case examines the response of an Australian aerospace company to market and supply chain changes through the 1990's. For some 50 years, the company maintained a substantial position in the Australian aerospace industry, primarily supporting Defence Department requirements. By the early 1990's, the company exported virtually all of its products and pursued a strategy involving innovation in support of its customers. The nature of changes through the 1990's is summarized in terms of market reach, market segment, typical production scope and company IP contribution (see Table 1). The particular focus area of this paper is the IP contribution aspect post - 1990.

Table 1. Case study company environmental changes

	MARKET REACH	DOMINANT MARKET SECTOR	TYPICAL PRODUCTION SCOPE	COMPANY I.P. CONTRIBUTION
PRE-1990'S	DOMESTIC	DEFENCE AEROSPACE	LIMITED QUANTITIES OF WHOLE AIRCRAFT, SHORT-TERM PRODUCTION	OTHER PEOPLE'S DESIGNS AND PRODUCTION CONCEPTS
POST-1990	GLOBAL	COMMERCIAL AEROSPACE	LARGER QUANTITIES OF PARTS OF AIRCRAFT, LONG TERM PRODUCTION	COMPANY DETAIL DESIGN AND PRODUCTION CONCEPTS

The broad direction of the Company over the 1990's was set by a relatively small number of strategic decisions, but their enactment was heavily influenced by market, supply chain and ownership changes along the way. An increase in the effective capacity of the organization to design sophisticated products was achieved through the implementation of an innovation network that allowed the company to operate with a relatively small core of specialist engineers, but access a breadth of capabilities as needed. It is further observed that whilst the company achieved radical change in its market position, this was via a succession of complementary incremental innovations that also reflected the company's response to changes in its operational environment.

The network that evolved is considered in terms of the actors, transactions and environment, with some illustration of the conditional nature of the transactions in this case and comment is made on the unique attributes of this innovation network

SOME KEY STRATEGIC DECISIONS

Some key strategic decisions were made prior to the 1990's based on trends perceived by the company management. These were:

- to introduce capabilities to manufacture components from a relatively new material, carbon-reinforced composites (initiated in the early 1980's)
- to focus engineering capabilities to design and develop major structural components for large commercial aircraft (initiated in the late 1980's)
- to seek partnership arrangements with large commercial aircraft manufacturers (initiated in the late 1980's)

These decisions positioned the organization well for the transition that took place in the 1990's. The company's commercial aircraft manufacturer customer base sought to change its relationship with suppliers through the 1990's, outsourcing some of the things that used to be done in-house. The evolution of customer requirements of their suppliers is illustrated in Table 2.

Some key strategic decisions made through the 1990's in response to various owner requirements, changing customer requirements, and opportunities to work differently within the customer supply chain were:

- the evolution of cellular manufacturing, team-based production practices to reduce costs, lead times and inventory
- establishing management and infrastructure along the lines of a large version of a "small" company rather than a small version of a "large" company – the historical paradigm. This lead to more outsourcing and collaborative activities and to a financial management focus on smaller units within the company
- the evolution of fast-track concurrent engineering competencies, which have not only reduced startup and production costs, but provided a source of competitive discrimination
- the adoption of new technology earlier in its life cycle
- the evolution of strategic alliances with selected suppliers, reducing overall cost by providing further value-adding opportunities for those suppliers, further reducing inventory and in some cases establishing joint R&D activities

Table 2. Some aircraft manufacturer supply chain requirements

CUSTOMER REQUIREMENTS	
CIRCA 1993	**CIRCA 1998**
BUSINESS • Fixed price, long term contracts • Ability to take on risk-sharing programs • Ability to manage multi-sourcing contracts • Ability to supply complete system or module	• Year-on-year price reductions • Greater emphasis on risk-sharing • Multi-sourcing plus help with "market access" sought • Clustering under global specialists with extensive knowledge sharing • Reduction of supplier base, working only with the best
PRODUCT AND PROCESS DEVELOPMENT • Right-first-time engineering • Joint development programs • Short lead time to first production unit • Ability to provide low-cost technical solutions whilst maintaining product performance • Technology leadership • In-house design capability • Low R&D cost	• Right-first-time engineering • Emphasis moving towards supplier development • Competitive advantage would require re-use rather than recreation of knowledge • Research collaboration and outsourcing to best practice suppliers • Technology leadership • In-house design capability • Low R&D cost, to be absorbed by supplier
PRODUCTION ACTIVITIES • Low price • Record of excellent schedule adherence • Short lead times for custom variants • Established reputation in aerospace and quality track record • In-house capability in key manufacturing processes • Ability to supply in kits, in aircraft sets, direct to the customer production line • Short lead time for new product options	• Low start price and continuous reduction sought • Schedule adherence and evidence of risk management practices • Support to JIT principles • Good quality performance must still continuously improve • Adoption of "Lean Manufacturing " principles • In-house capability in key manufacturing processes • Ability to supply in kits, in aircraft sets, direct to the customer production line • Short lead time for new product options
Successful suppliers will meet a range of criteria in the three areas above, to produce world class quality and delivery performance combined with least cost, and sharing program financial risks	

Through the 1990's, the company growth and profitability came mainly from the design and manufacture of large carbon-reinforced composite aircraft structure assemblies. This was not achieved without difficulty, as the combined effect of the decisions described above was to substantially reduce the management and administrative support infrastructure of the company. However, at the same time, some new R&D and collaborative management competencies had to be acquired.

SUPPLY CHAIN RELATIONSHIPS

Through the 1980's, the airline operators sought to reduce their aircraft related costs by using high technology approaches to the reduction of operating and maintenance costs, even if this meant some increase in capital costs. Benefits from this strategy started to bottom out, so in the 1990's, the airline operators began to seek reductions in aircraft capital costs, whilst retaining the levels of performance then achieved. Aircraft manufacturers sought to reduce costs through the whole supply chain. The case study company was impacted at both ends, with its customers requiring price reductions and its major suppliers having little capacity for price reduction, as the aircraft manufacturers rigidly specified the materials produced. The case study company evolved a three pronged approach: (1) change the relationship with its customer to reduce their transaction costs and to seek design changes that would reduce its internal costs; (2) pursue a high rate of internal cost improvement; and (3) work with its suppliers to reduce transaction costs and provide value adding services that reduced the overall product cost.

Whereas there was a reluctance to change designs in the 1980's, as this was very expensive, the aircraft manufacturers became more amenable to cost-reducing changes, if the cost and speed of introduction could be optimized for fast payback. In addition, the aircraft manufacturers sought to have their major suppliers become risk-sharing partners in the launch of any new product.

These circumstances changed supply chain relationships in a number of ways:

- the case study company regularly had engineers working within its customer's organization, at minimal cost to the customer, and there were visits encouraged by supplier shop floor personnel to see if a supplier action could reduce customer internal production costs.
- visibility of the flow of work through the case study company production facility was provided to the aircraft manufacturers in support of JIT practices

- in a similar way, the case study company had visibility of the progress of its orders with it's material suppliers and developed multi-faceted alliance arrangements with key suppliers.

The R&D function assumed a more strategic role in the company, but it had to be closely integrated with customers, the production function and the company's key suppliers. Acquiring more capability with less resources was the norm.

THE EVOLUTION OF AN INNOVATION NETWORK

The strategic decision to establish design of the products that the company produced as a source of competitive advantage had one significant management issue associated with it: the discontinuous nature of design activities. A major project design was only started after a contract was obtained from the customer, resulting in significant peaks and valleys in the demand for specialist engineering resources. The case study company had initially abandoned a number of its traditional broadly-based engineering functions that were not regularly needed in its new operating environment and it evolved a practice of keeping some specific design activities in-house, whilst undertaking some specialist activities collaboratively. It was considered that this practice enhanced opportunities for innovation, and might be regarded as an example of an innovation network (as compared with a production supply chain network or a learning network). Similar approaches have been observed in a six-country study in Europe (Hales, 2001), where the multiple knowledge flowing from a range of network connections greatly enhanced the traditional approach to new product development. This is illustrated in Figure 1 below, and highlights the existence of a number of different kinds of collaborative partners at different stages in the life cycle of a project.

In the case study company innovation network, some partners would only participate in some stages of the project life cycle and some would play different roles in successive stages. For example, a key supplier of production materials or services may provide "consultant" advice during the product specification and development phases. This advice needed to be the best for the project, not necessarily the best for the supplier, which required mutual acceptance that a beneficial long-term relationship exists. For the current suppliers, such relationships had developed. However, having new partners join the network is regarded as introducing additional risks that would have to be managed. Project management practices and decision-making processes of the participants had to be aligned in some way to minimize communication and schedule risks. If trust and confidence was not yet built, contingency plans and alternative sources of supply may have to be identified, adding cost and complexity.

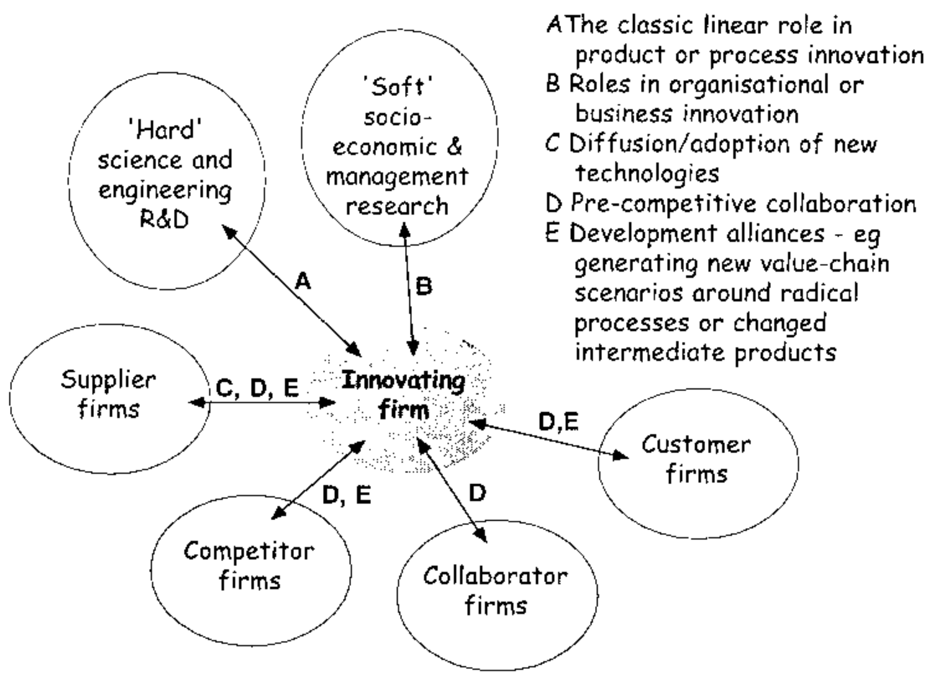


Figure 1. Typical collaborations in an innovation network (Hales, 2001)

Innovation is about creative outcomes and R&D can provide significant inputs, so the search for innovation considered options available from research, and, accessing technology earlier in its life cycle became a norm for the case study company. Spending a lot of time refining and consolidating research that may only impact part of a total solution may not be helpful if this compromises getting early market access, even though it might be considered that technical risk is reduced by the additional work, or that the solution will be more refined. The point is, technology is only one of the risks to be managed.

To consider all influences on the decision to adopt new technology earlier, research, marketing, manufacturing and finance perspectives were combined. In the case study company, many engineers were rotated through research, product development and manufacturing assignments to help provide balanced views and a particular engineer may follow a particular new technology introduction through the whole cycle from laboratory to application over a period of a few years. In addition, external research partners were encouraged to interact directly with customers in conjunction with the company's marketing and technical staff. This helped in maintaining an appropriate focus on the research activities and to maintain customer visibility on company research initiatives. Financial models were developed in considering options that might be offered to a customer. The company also introduced the outcomes of methodology research that enhanced the product development management process for trial at an early stage of their development. The result was a customer perception of an innovative and competent company that was as capable as larger competitors.

Most research was carried out collaboratively through two Cooperative Research Centres in Australia and an international Intelligent Manufacturing Systems program. The objective was to capture a diversity of views and opportunities and to tap into a broader network of contacts. Like many businesses, the case study company has a strong dependency on some particular suppliers of unique materials or components. In this situation, developing joint research interests and a lead-user relationship offered early opportunities for innovation for both parties and also helped appreciate what new applications might be possible in the near future.

Faster product development time is a competitive requirement in most industries, putting pressure on the development process, the supply chain and manufacturing changeover times. Development time frames were targeted in weeks, not months. What evolved in the case study company in response to this environment was a network of three overlapping concurrent engineering activities:

- one was concerned with concept development involving research, design, marketing, manufacturing supply chain and finance option development. New approaches to tooling, and rapid prototyping techniques were also considered

- one was concerned with product development in concert with the customer to introduce a specific product into manufacture. Supply chain partners were an integral part of this activity
- one was concerned with on-going support systems and on-going technology or supply chain option development to facilitate the other two. For example, there may be an IT support function integrated with a product development team. Lessons learned were also incorporated in underlying practices

With so many things happening in parallel, especially where some participants may be remote from each other, maintaining visibility and control can become an issue and focus on the desired outcomes must be maintained. Complex military programs have utilized a sequence of formal reviews to assure goals are met. A commercial product development "Stage-Gate" technique is favored by many to integrate product development with business needs (Frost 1998). Others argue that such approaches are too cumbersome and that maintaining a close association with a lead customer can achieve better results faster (Buisson et al 1998). The case study company utilized aspects of all of these approaches at any stage having more than one option for achieving project goals.

Data management required careful control. Where long lead-time items can adversely impact on project development times, the controlled flow of technical data must link with these requirements. For example, tooling suppliers participated in tool design and material ordering long before detailed designs were completed. This required a progressive release approach to data management and baseline control on the part of the project team, and, a different form of participation by the tooling supplier who was used to getting a full data pack to bid on. Getting this process wrong can lead to financial and schedule risk. Freezing some things while keeping options open on others requires a different approach to manufacturing planning. Therefore, all suppliers had to be involved early so everyone understood the whole process and the need for a target pricing approach to business. Further details and an example of one project are given in Beckett (2000).

Adopting technology earlier in its life cycle can increase the project risks to be managed. Something may not work out as expected, the technology may not be accepted by end users, or costs may be higher than expected. The Aerospace industry, despite the high technology image, is relatively conservative. Whilst this is regarded as a virtue by frequent flyers, it can lead to long and expensive product or process validation arrangements. Consequently, the case study company generally adopted a fast-track incremental, rather than radical change approach. Initially, a technology was implemented in a relatively simple application, with a "technology demonstrator" having been produced under real production conditions prior to that. Then, progressively more sophisticated applications would be developed. Such arrangements helped manage risk, but they also altered the development process itself. For example, research continued in parallel with development to provide options if things were not working out too well. This helps explain the overlapping concurrent engineering processes described earlier

Developing new product and new manufacturing processes in parallel adds another risk dimension in the context of fast-track product development. If things get out of synchronization, then the impact on cost and schedule can be very significant. And while a "stage-gate" type of approach is helpful at a macro-level, a succession of lower level intermediate milestones is also needed for producibility studies that start at the same time as design does. In these circumstances, it was essential that both the concept stage work was sound and that options for alternative approaches were always available. In the context of a single project, running options in parallel with the main program may seem expensive, but overall, this is not the case, as these options could generally be used on another project at a later time.

Keeping all project participants synchronised, particularly in international projects, requires formal communications, precise technical data coordination and the establishment of collaborative management functions. A focus must be maintained on information that is critical to the project, or the level of effort required will not be consistent with the benefits obtained. Information must be created once and re-used for different purposes with links to the source being maintained. Otherwise, project data sets will become inconsistent over time. Many software products have promised to deliver such structures, and they can be effective within a particular organization. However, when different organisations are involved, people must manage the interfaces.

DISCUSSION

The case study company evolved a strategy of collaboration to support fast-tracked product development in conjunction with its customers. Alternative strategies of maintaining all competencies in-house, or acquiring them through mergers and acquisitions, would have increased company costs or required greater financial investment. The company had a history of collaboration on military projects, but this generally involved one project collaboration at a time lasting several years. It participated in eight product development projects of different kinds through the 1990's, some involving the customer taking the lead, and others involving the case study company taking the lead. The nature of interactions with the customer differed in each circumstance, but all involved a team in the customer's program office and a parallel team in the case study company. Collaborators and suppliers were not always the same for each project, but were generally drawn from a pre-existing network of previous collaborators. A higher level of potential schedule, cost and technical risk had to be managed, which was achieved, in part, by maintaining a variety of options throughout the development of a particular product.

To obtain an overview of the practices reflected in the case study, the innovation network has been characterized by considering some of the transactions taking place, as suggested by Todeva (2001), who defines a generic business network as follows;

"Business Networks are sets of transactions based on structural formations with dynamic boundaries that comprise of interconnected elements (actors, resources and activities); Networks accommodate the contradictory aims pursued by each actor, and facilitate joint activities and repetitive exchanges that have specific directionality and flow of information, commodities, heterogeneous resources, individual affection, commitment and trust between the network members."

Actors in the case study company were the company itself, its customers, its collaborators and its suppliers. Resources were those applied to a particular project and complementary assets (e.g. special testing facilities) held outside of the network. Some activities related directly to the project itself and some related to options that were under development in parallel.

Todeva's (2001) assessment of the literature in this context leads to the following suggestions:

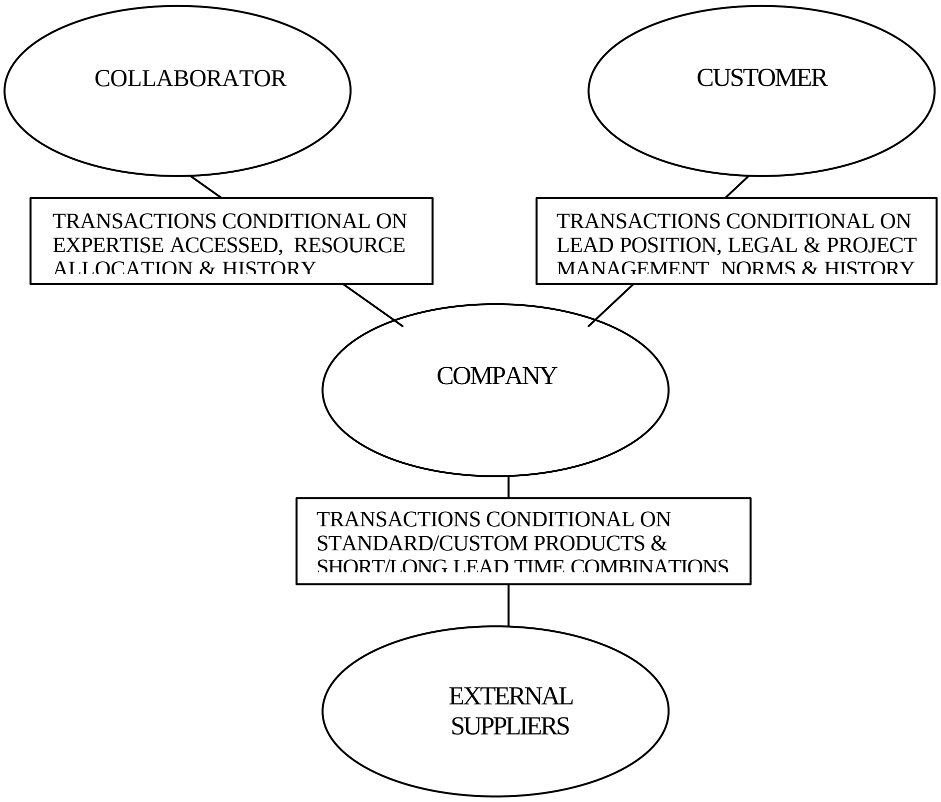
- *"Each network has limited resources, and different members have different access to these resources."* In some of the case study company projects, additional resources had to be provided by one collaborator to support another from time-to-time in order to maintain schedule, and some participants had access to specialist resources outside of the network.
- *"The unique feature of networks is that they accommodate inequality within their boundaries. This inequality is further enhanced by the division of labour and the specialization pursued by each individual firm in the business network."* In the case study, the collaborators, suppliers and customers were of quite different size and power and vertical rather than horizontal integration was the norm, with the case study company generally assuming a co-ordination role.
- *"Recognize the embeddedness of market transactions in the structure of social relations. However, the practical consequences of that fact remain hidden in implicit assumptions about network ties, positions, and dyadic relations between actors in hierarchical and network structures".* The formality of network ties in the case study company projects varied considerably; some being based on rigorous contractual and project management practices, and others being influenced by prior interaction experience. Larger partners also tended towards more formal (and less flexible) arrangements. Where trust had been built between some key individuals in the collaborating companies, less frequent, but richer communications and faster problem-solving was the norm.
- *"The relational approach, developed by the IMP Group (1997) at Uppsala University has introduced an alternative conceptual framework that enriches the dyadic model of relationships. According to their interaction model, network research should focus simultaneously on three aspects of networks: the participants, the interaction process, and the environment within which interactions take place. The interacting parties are conceptualised as the individuals, and the organisations they work in, with the size, the structure, the strategy, the experience, and the*

technology employed by these organizations" (IMP Group, 1997). The environment within which interactions took place was fixed price, fixed development time, but a dynamically changing environment where significant risks had to be managed. The experience of the case study company was that having the right individuals in the right place at the right time was essential to rapidly progress a project, particularly in dealing with unexpected issues. The interaction processes varied from member to member, depending on their internal practices and their project role

- *"Control over the value chain and the value system (Porter, 1991), can explain relations of power and domination between inter-linked economic agents"*. The case study company was generally positioned such that both customers and major suppliers held considerable power and the company had to establish special kinds of long-term relationships with both groups to establish some influence on project outcomes.
- *Therefore, the interaction of actors in a network modifies the very framework for interpretation of market information in a network and the way companies assess and respond to market signals.* The case study company certainly obtained different market signals through different partner channels (collaborator, supplier, customer) about project health, company performance and the circumstances of competitors who might be working on another aspect of the same project. The company seemed to need both formal inter-enterprise relationships and some kind of individual ally within each participant group. Within the customer organization, a respected ally who could influence the customer on behalf of the company and interpret formal communications for it was found helpful. Within a supplier organization, trust built from previous referrals that had directed new business to the supplier seemed to facilitate a better flow of information. Within the other collaborating organizations, application of their ideas and joint marketing missions built personal relationships. Exchanges of personnel with some of the network participants also built a supplementary informal network.

Todeva (2001) argues "that the lack of a formal hierarchical structure and chain of command in business networks does not mean that transactions and exchanges within a network don't have prescribed directionality. They are subject to positional relations and depend on the position of each network member, the priorities set by these actors, and the distribution of control between them. Positional relations could be observed in all types of social, technical and business networks." The case study company operated in a hub and spoke style of network in all of its projects, but the nature of the transactions was contingent on a number of factors. These observations and the preceding innovation network description have lead to the general representation shown in Figure 2, which illustrates that differing conditional factors influence the nature of transactions with each generic type of actor.

Figure 2 Case study company typical network and transactions



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The innovation network environment of fast-track development and risk management also influences the kinds of transactions with different participants. For example, the influence of the external supplier conditional parameters on degree of standardization and lead time arise as follows: a particular product will commonly be constructed from some standard parts, some standard parts made to special order, some custom parts made from standard elements, and some unique custom parts, leading to situation-dependent top-level actions as shown in Table 3.

Table 3. Some component and materials acquisition strategies

	STANDARD PRODUCT	CUSTOM PRODUCT
SHORT LEAD TIME	• Maintain catalogue up-to-date • Fast-track order process	• Establish order process • Understand order parameters
LONG LEAD TIME	• Integrate into project development plan • Understand options	• Integrate with product development team • Set targets jointly

CONCLUSION

The case study company was reasonably well positioned to start the development of the innovation network described here, having prior collaboration experience and having begun to establish an appropriate technology and core competency base. However, the changing requirements of its customers and the larger number of projects undertaken on a global basis introduced a more demanding environment. Both the external environment and the case study company strategies to respond to it created the operational environment for the evolution of an innovation network. Innovation involves divergent thinking that thrives on disorder, imagination and ambiguity, in contrast to most convergent thinking business norms that seek order, measurement and predictability (Hickman and Raia, 2002:14) This is reflected in the case study innovation network where a fast-track strategy and project management practice of keeping multiple options available, whilst identifying and managing risk dynamically, became the norm. It is suggested here that these dynamics make an innovation network different from a production supply chain network or a learning network. The nature of the transactions between participants is different for each project, is dependent on a number of contingent factors and may change as the project proceeds.

Nevertheless, the notion of examining such practices in a generic way through consideration of the generic actors, the conditional nature of transactions between them, and the environment within which transactions take place can help us to better understand what is happening in such a network.

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