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Innovation management processes for technology based knowledge transfer companies – the impact of the results of the ESRC Innovation Programme

AIRTO Paper 2001/2

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INNOVATION MANAGEMENT PROCESSES FOR TECHNOLOGY BASED KNOWLEDGE TRANSFER COMPANIES – THE IMPACT OF THE RESULTS OF THE ESRC INNOVATION PROGRAMME

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EXECUTIVE SUMMARY

Background

From 1995 – 2000, the UK Economic and Social Science Research Council (ESRC) sponsored a major programme of university research into industrial innovation. The 25 sub-projects within the Innovation Programme (IP) have produced a significant contribution to innovation literature, proposing a range of new models and insights drawn from a wide range of industry sectors.

In year 2000, the President of AIRTO, Dr Brian Blunden, and the ESRC Director of Research, Mr Chris Caswill, were instrumental in encouraging ESRC and members of the AIRTO community to undertake research into the application of IP results to the knowledge transfer sector. This report covers work undertaken by TWI, which has tested IP results against its own experience, and that of other sector bodies. IP models have thrown new light on knowledge transfer innovation processes, and some of them have been extended and supplemented by the present work.

Objectives

The main objectives of the work were to

- survey and evaluate the suitability of innovation management tools and techniques resulting from the ESRC Innovation Programme for more widely-based technology organisations
- test these on the development of commercial technology prospects drawn from on-going innovations involving TWI and industrial partners
- present case studies based on the tests undertaken
- identify the most appropriate tools and techniques for technological applications, detailing their applicability, benefits and limitations
- highlight further development opportunities.

Approach

The relevance of innovation management tools, techniques and results from the ESRC Innovation Programme were considered in relation to the innovation processes of the researchers' parent organisation (TWI Ltd) and to actual innovations currently being exploited by TWI. The tools and techniques were also used with a number of other organisations in order to assess their utility to the range of similar organisations.

Summary of TWI findings from the research project

- The ESRC Innovation Programme has provided a wealth of information, analyses and models that can be used to help understand and improve innovation processes.

- These results of the Innovation Programme have been successfully adapted to the specific case of innovation management in knowledge trading companies, as has been demonstrated by the examination of innovation at TWI. New and modified models have been proposed for innovation processes in knowledge trading organisations.

- These models developed by this project and derived by this project from the ESRC Innovation Programme results have helped in the understanding of innovation management processes both at TWI and for the other organisations surveyed.

- Comparison of TWI with a range of other similar organisations has shown there is a common belief that innovation is crucial to the continuing success of such organisations.

- There is limited systematic understanding of the details of the innovation processes that occur within knowledge transfer companies, by both management and staff. This results in restrictions to the measures used to promote and direct successful innovation.

- There is need to clarify the concepts of innovation management by promoting the supply of information and education to management and staff, and to introduce further measures to enhance innovation performance. These measures involve the internal management and the funding environment in the UK.

- The results of the project will be of direct use to TWI in understanding its innovation processes and hence achieving its innovation objectives within its corporate plan. The project was also of benefit to the TWI staff involved in its execution by increasing their understanding of both the theory and practice of innovation management.

Conclusions and recommendations

1 A new DTI supported programme should be instigated to invest in early stage business development. Evidence is provided in this study which demonstrates that investment in AIRTO member activities produces a multiplier effect in private sector industry of between x17 to x70. This research shows that innovation stimulation and new enterprise creation are central to these activities. The scale of these activities, and thus their contribution to growth in the UK economy, are constrained by the level of AIRTO member (and other organisations) revenue surplus. A publicly funded programme is needed to channel pump-priming funds into early stage innovative high-tech investment. This would be similar to that programme which is utilised by the Fraunhofer Gesellschaft in Germany. Knowledge transfer organisations within the AIRTO community could collaborate to administer effectively such innovation stimulation. This could include the provision of venture capital and business angel support through E-SYNERGY.

2 In this research, new business incubation is demonstrated to be complex if directed in a way which is effective in leveraging the UK economy. This work illustrates the unique innovation support skills available to business incubation among the AIRTO community. A new initiative should be implemented by government (Treasury and DTI) to provide financial incentives for universities and Regional Development Agencies (RDAs) to work in partnership with knowledge trading companies. This would be more effective than present incentive schemes which lack understanding of the complex supply chain process involved in value-added knowledge transfer required for effective and lasting high-tech business incubation.

3 The ESRC/AIRTO Awards Scheme pilot studies have demonstrated a real contribution to infrastructure development in knowledge transfer from academia to industry with leverage on attitude and work practice change in industry. The Scheme should be continued on the present basis. Consideration should be given to extending the Scheme. This would increase knowledge transfer from academia into UK management. It would complement schemes such as TCS and operate at a different level. Over several years it would change management attitudes and competences in relation to investment in R&D and to risk taking in technology based innovation. The need for this change is shown by the present negative pattern of the DTI Research and Development Scoreboard.

4 The ESRC Innovation Programme has provided a wealth of information, analyses and models that can be used to understand and improve innovation processes. ESRC research on innovation should be continued.

5 The results of the Innovation Programme have been successfully adapted to the specific case of innovation management in AIRTO members, as has been demonstrated by the examination of innovation at TWI. New and modified models have been proposed for innovation processes in the knowledge trading businesses.

6 The models developed by this project and derived from the ESRC Innovation Programme results, have helped in the understanding of innovation management processes both at TWI and for the other organisations surveyed.

7 Comparisons of TWI with the range of other knowledge trading companies have generated case studies which show there is a common belief that innovation is crucial to the continuing success of such organisations, and that similar interests and concerns exist within many other organisations.

8 There is limited systematic understanding of the details of the innovation processes that occur within knowledge traders, by both management and staff. This results in restrictions to the measures used to promote and control successful innovation. These findings are likely to apply to universities and RDAs. The role of knowledge transfer companies is critical to bridging this gap in understanding and practice.

9 There is need to clarify the concepts of innovation management by promoting the supply of information and education to management and staff of knowledge trading companies, and to introduce further measures to enhance innovation performance. These measures involve the management of AIRTO members, but also include the UK funding environment in which they operate.

10 The results of the project will be of direct use to TWI in understanding its innovation processes and hence achieving its innovation objectives within its Corporate Plan. The project was also of direct benefit to the TWI staff involved in its execution by increasing their understanding of both the theory and practice of innovation management. This experience will be shared with other knowledge trading companies in the private sector but particularly by recruiting them into the AIRTO community.

1) Introduction

From 1995-2000, The UK Economic and Social Science Research Council (ESRC) sponsored a major programme of university research into industrial innovation. The 25 sub-projects within the Innovation Programme (IP) researched innovation policies, processes, attitudes and beliefs in a wide range of industry sectors, including large companies, and SMEs in the public and private sectors. The results of the IP represent a significant contribution to innovation literature, proposing a range of new models and insights.

The background to the ESRC Innovation Programme is summarised in a final document issued by the Project Director, Dr Fiona Steele, at the end of the main phase of the project. A copy of her report and summary of the projects involved are provided in Appendix A.

From the outset, the Innovation Programme placed emphasis on the importance of exploitation of new ideas: invention alone is not enough. This theme is squarely in line with the objectives of today's AIRTO members.

In year 2000, AIRTO was instrumental in encouraging ESRC and members of the AIRTO community to undertake research into the application of Innovation Programme results to the knowledge trading sector. AIRTO members specialise in innovation and technology transfer and enjoy close relations with industry. Their innovation approaches have a big impact on their clients, but formal study of these processes has been relatively limited.

This report covers work undertaken by TWI, which has tested Innovation Programme results against its own experience, and that of other sector bodies. Innovation Programme models have thrown new light on knowledge transfer innovation processes, some have been extended and supplemented by the present work.

The following sections of the report cover the background to TWI and the application of Innovation Programme tools and insights to current and possible future practice. The objective was to gain new insight into methods that might improve innovation output from knowledge transfer companies operations, thus benefiting both the research and industrial communities.

2) Research Objectives

This project took innovation management tools, techniques and insights generated by the ESRC Innovation Programme and applied them to the innovation processes of the researchers' parent organisation (TWI Ltd.) and to actual innovations currently being exploited by TWI. The tools and techniques were used also with a number of other organisations to assess their utility to a range of similar organisations.

The main objectives of the work were to

- survey and evaluate the suitability of innovation management tools and techniques resulting from the ESRC Innovation Programme for more widely-based technology organisations

- test these on the development of commercial technology prospects drawn from on-going innovations involving TWI and industrial partners
- present case studies based on the tests undertaken
- identify the most appropriate tools and techniques for technological applications, detailing their applicability, benefits and limitations
- highlight further development opportunities.

The researchers also had a more general objective trying to identify whether current AIRTO member innovation management processes limit their innovation (and hence growth) potential. There appears to be a contradiction between industry's increased outsourcing of technical functions and activities, and relatively low growth among knowledge trading companies. Some AIRTO members have not grown at all, in an era where growth might have been expected.

This objective underlay all the activities of the project, but of particular relevance were comparisons made between the innovation management processes of UK knowledge transfer companies and those of the Fraunhofer Institutes in Germany, two of which were visited as a part of the project.

3) The ESRC Innovation Programme – Key Results

The 25 projects funded under the ESRC Innovation Programme cover diverse aspects of the innovation process. All were found to have some relevance to the current work, with several having an immediate resonance with the analyses being undertaken.

Storey's work on innovation processes and his "Theories of Innovation" matrix (Storey, 2000) has allowed the identification of pathways not previously systematically characterised for overall organisation and individual inventions. Modifications to the matrix have been made by the current researchers to make it applicable to AIRTO members in general and TWI in particular.

Additions to the matrix were made to show the dynamics of the innovation process within knowledge transfer companies. These modifications were discussed with the original author, prior to being used for the assessment of the case studies at TWI and as a part of the presentation to other AIRTO members. For both of these the modified matrix proved to be effective in helping to understand the processes involved in innovation (see section 5.9). It was found that the progress of the five TWI case studies could be "mapped" on the modified diagram, and it provided a

rational view of the alternative innovation routes open to an organisation. The modified diagram also engendered resonance and concern amongst the knowledge trading companies surveyed, with the realisation that there was a route for ideas being lost, for which there was currently no measure of significance.

The work by Quintas confirmed that there were parallels in private sector commercial companies to the aspects of innovation found in knowledge transfer companies (Quintas, 2000). The identification of innovation as a strategic priority was found, but in the private sector commercial case this was not reflected in the resource allocated to it. The same strategic priority in knowledge transfer companies is matched by a limitation in resource generally dictated by finance availability rather than desire. Innovation not being recognised as an organisation-

wide activity in all functional areas was another common theme, as was more flexible employment strategies.

Quintas also identified the trend towards outsourcing R&D. This raised the question of whether AIRTO members were being innovative enough in their customer relationships to benefit from this trend.

Coombs work on "Management in Knowledge-Intensive Organisations" (Coombs, 2000) resulted in an audit tool for an organisation to do a "healthcheck" on its knowledge management practices. Within TWI this has been used to give a comparison between different technical areas and functions on the status of knowledge management processes, in order that the organisation can harmonise and improve its activities. With other AIRTO members it was proposed as a tool for use in the benchmarking exercise, but a reluctance to use the audit tool was encountered, probably resulting from inertia because of its relative complexity.

Morgan & Maddock discussed the role of senior management in providing a protective environment for the innovation process (Morgan & Maddock, 2000). Although the underlying ideas were found to be of interest, the work was based on the NHS and the detailed study had limited relevance to AIRTO members. However, the ideas were developed for the knowledge trading sector by the present project. In particular, it was found that they could be illustrated by an adaptation of the Blake and Mouton matrix (Blake and Mouton, 1965).

The model developed through a series of matrices illustrates the need for strong leadership if invention is to become effective innovation, a theme running through many of the Innovation Programme projects. Two of these matrices are described in more detail in section 5.10.

Blackler's work on innovation in high technology organisations provided a model of roles and interactions that occur in commercial manufacturers (Blackler, 2000), but was also directly relevant to knowledge traders. His identification of the core processes involved in innovation: domain, boundary and contextual innovations, served to present a wider view of innovation to AIRTO members.

Bartlow's study of relationships in the construction industry was not directly relevant to AIRTO members, but the concept of positive partnering between client and supplier does provide both a model and practical illustration that can be

adapted to benefit the relationship between knowledge traders and their customers, particularly when dealing with large and complex projects (Bartlow, 2000).

A more general benefit of the Innovation Programme has been the propostion of a "taxonomy" of innovation. In a discipline where confusion and misconception exists, the suggestion and agreement of common terminology is a positive and valuable development.

The wealth of the material resulting from the Innovation Programme provided a significant resource for this work with AIRTO members and will continue to form part of the basis of further reporting and analysis. However, there must always be some limitations to the material that is available.

In the case of the Innovation Programme, two criticisms were levelled at the projects during discussions within TWI and with other AIRTO members. First, with some exceptions, the projects tend to concentrate on successful innovations. There are also lessons to be learnt from failures, but perhaps it is more difficult to find organisations that are willing to provide these as case studies. Second, the models from the programme with which most people could identify were those that were relatively simple. Some were viewed as being over complicated or too academic for mainstream use. However, it may be observed that the origins of the projects were largely academic, and the role of this project is to demonstrate their value for practical usage.

4) RTO evolution and business perspectives

A brief history of the interaction between technology development and RTO business is presented, using TWI as an exemplar.

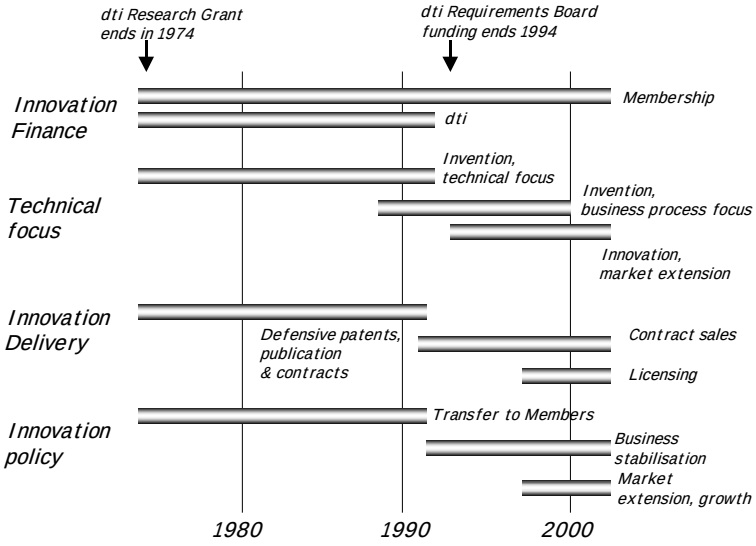
Research and Technology Organisations (RTOs) have developed in the UK since the 1920s to meet the demands of government and industry for focused research and technology transfer across a range of technical disciplines and industry sectors. The current activities and capabilities of these organisations may be explained in part by the industrial history of their target markets, and changes in government science, engineering and technology policy over the past fifty years. At the time of their formation, most RTOs were at least partly reliant on government support (either by grant aid or matching public and private funding). In subsequent years, the proportion of public funding has been steadily reduced, until by 2001, AIRTO members do not have dependence on public funding.

RTOs have had to change their activities over the years to maintain business stability as government policy, industry and technologies have altered. Some have enlarged their footprint of coverage in response to market demand, or have diversified. Others have had to amalgamate, or even cease trading. In no case however, has an RTO grown huge, even when commercial flexibility and apparent market demand were significant. The reasons for this paradox are important, as they also throw light on RTO innovation attitudes, government support infrastructure and address the general objective of the current project discussed in section 2.

4.1 TWI as an exemplar RTO

TWI specialises in joining and allied technologies for all industry sectors, and has preserved its modus operandi based on company membership from the organisations inception in the 1940s. Since 1968, it has included a professional institution, which has significant influence on policy, even though the financial impact of professional activities is small. This combination of RTO and professional structures is unique.

A time-line diagram of TWI's evolution over the last 25 years, Figure 4.1, illustrates major features relevant to its innovation activities, including key changes in



funding, innovation focus, and market diversification.

Fig. 4.1 TWI innovation activities 1980-2001

While TWI is, in many ways, a typical RTO, it should be remembered that joining technologies are both safety-critical and industrially pervasive. TWI is therefore well placed to overcome setbacks in a specific industry, while a strong growth in new manufacturing technologies and materials has underpinned its ability to diversify into new technologies and industries.

4.1.1 TWI until 1994: Innovation and Technology Push

Innovation has been a strongly expressed part of TWI's mission for decades, but that innovation has often, in the past, been confused with invention. Historically, TWI's mission with new technologies was to develop ideas to the point where they could be taken up by the R&D laboratories of end users. The consequences of this were twofold: TWI did not realise any substantial income from licensing its inventions, and because the primary focus was technology, staff were not fully exposed to the commercial realities of industrial innovation.

The internal R&D capability of many manufacturing companies became more limited and focused through the 70's and 80's. Industrial research budgets reduced and numbers of technical contacts were lost as industrial R&D groups slimmed. This trend was accompanied by changes in government industrial research policy: TWI's matched Research Grant ended in 1974, and Requirements Board funding which replaced it, ceased in 1994. TWI was, to some extent, prepared for this change as it had developed alternative funding streams via collaborative European projects and intensified efforts to secure privately funded contracts and consultancy. Neither of

these mechanisms was entirely satisfactory as a support for the early stages of innovation, and pump-priming finance remains an issue to the present day.

Even though it would be possible to raise alternative finance (e.g. venture capital) to support innovation, TWI has avoided this route because of concerns that this might undermine the organisation's ability to provide independent advice and services, and to address the requirements of its members. For this reason, TWI's ability to engage in the early stages of innovation is limited by the amount of internal funding available.

4.1.2 TWI 1994 – 2001: Business Focus and Market Extension

1994 was a critical year in TWI's development. Loss of underpinning funding coupled with a difficult business environment posed significant financial threats. Changes were essential, and to help understand the challenges involved, TWI produced for the first time, a formal model of its innovation cycle, Figure 4.2.

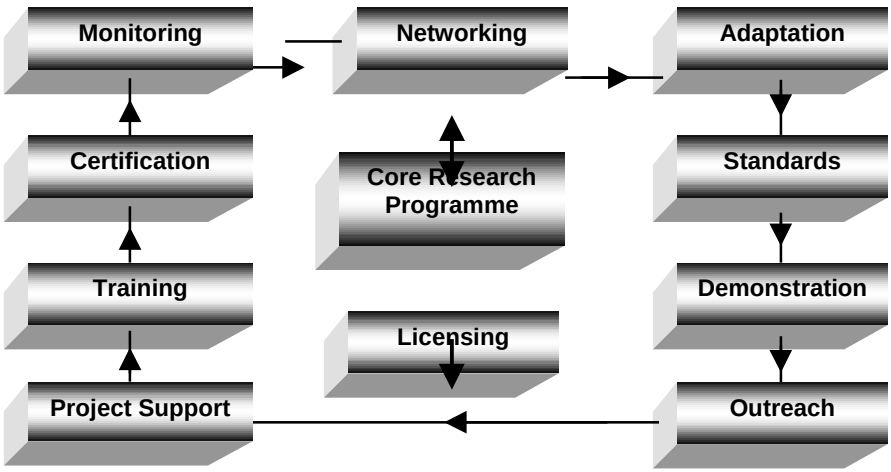


Fig. 4.2 TWI Innovation cycle (1994)

Although simplified and focused on TWI's traditional business approach, this model allowed discussion of linkages and dependencies between different parts of the business. It also revealed a need to focus even more closely on the needs of industry sectors, through adaptation of technology to suit commercial needs, development of standards and demonstration of feasibility. These technology transfer activities allowed TWI to bid for projects and training activities that formed the commercial core of the business.

The outcome of this analysis was the development of industry teams, who had responsibility for understanding specific sectors. TWI was reorganised along matrix lines, and refocused on the business needs of its members. Industry teams worked

in association with the technology-based research departments that acted as budget holders.

The industry teams acted as a focus for formal consultations and events with sector groups, but played little part in project winning or administration. Underlying commercial practices were slow to change, and there was a clear emphasis on technology push and technical reporting lines as a means for driving the business forward.

From 1994, TWI made a series of process innovation developments in the field of technology transfer. These projects, under partial DTI and EC sponsorship allowed the development of services directed at the needs of SMEs and supply chains. Although TWI was experienced in technology transfer, the needs of the general SME market were new, and resulted in the development of a new range of products which were made available to SMEs and member companies as a whole. A key feature of these services was technology delivery via TWI's JoinIT™ Internet site, an activity that is continuing to the present day.

A "product" innovation during this period was a partnership with MPC to plan and develop a technology park adjacent to TWI's Cambridge site. This ongoing venture will allow a substantial redevelopment of TWI's laboratory facilities and will also secure an income stream to underpin future research activities.

Currently, TWI's technical innovations and licensing policies are focused by a series of corporate plans. These integrate the objectives of technical and business-focused staff, and have resulted in a steady change away from invention and technology push policies towards innovation, licensing, and market-focused business developments.

The latest stage of this development is the redefinition of TWI's matrix structure in 2000. As a result of this, Industry Team Managers now hold responsibility for income budgets, while Technology Departments are charged with delivery of services through these groups.

The objective of all these developments is to produce a real change in TWI's operating culture and trading environment, generating revenues that can be used to pump-prime further innovation activity and extend membership services.

4.1.3 TWI's Current and Future Environment

A feature of TWI's strategy has been the retention of company membership as a central mechanism. Members represent a continued source of financial stability and a defined marketplace for TWI services and products. The technical focus of TWI-Member relationships allows interactions that are simultaneously commercial, professional and committed to nurturing the clients' business: a significant advantage over conventional consultancy business models.

The changes of the last twenty years have seen TWI emerge from a heavily subsidised technology-push environment to a more exposed, but more market-oriented position (Houldcroft 1996). This trend is likely to continue for the foreseeable future: the process innovations that are in hand, with e-commerce,

licensing and site development, are intended to allow flexibility to invest in further technical innovations, while also allowing market developments in new sectors.

While TWI's future appears reasonably secure, its growth potential is squarely identified with its ability to innovate. A combination of unfocused invention and technology push will not guarantee survival in the emerging global economy.

5) Application of ESRC Innovation Programme Results to TWI

TWI is a knowledge-based organisation that has been focused always on new technology developments. The success of its innovation effort has varied over the years, but it has been recognised as a key component of its activity, and has therefore been intensively debated internally.

Blending this rich internal environment with the diverse outputs of the ESRC Innovation Programme is not easy, as they are both complex. The approach taken in the current study has been to use TWI's current innovation models as templates, testing their integrity against selected Innovation Programme findings.

As previously discussed all projects within the Innovation Programme had some relevance to TWI. Nevertheless, it was clear from the outset that some were of particular significance at TWI's current level of understanding and stage of business development. These models and insights have therefore been highlighted in the following analysis.

5.1 Classes of innovation

Three main types of innovation are relevant to TWI:

- technical innovation (changes to its technology portfolio)
- process innovation (changes in how business objectives are approached)
- product innovation (changes in what the organisation aims to deliver).

5.1.1 Technical innovation

TWI has concentrated on technical innovation, because this is a key business driver, and also one with which most members and staff can identify. Recent examples which are part way through the innovation process include:

- Friction Stir welding (a novel generic welding process)
- Clearweld™ (a method for laser welding plastics and cloth)
- Vitresyn™ (a hard scuff-resistant coating technology)
- Barrikade® (a fire resistant insulating material)
- AdhFAST™ a mechanical fastener/adhesive bonding hybrid assembly technique.

The branding of these inventions is evidence of TWI's commercial innovation strategy, and both project and license income is being sought across supply chains in many sectors.

5.1.2 Process Innovation

Process innovations have been undertaken in response to perceived changes in markets or funding. An example mentioned earlier is the introduction of matrix organisational structures, and their modification to increase alignment with industry interests. Further examples include the changes required to meet ISO9001, TickIT and Investors in People accreditation. These changes have affected the underlying culture of TWI, and are part of a long-term pattern, linked closely to the objectives of the rolling corporate plan.

5.1.3 Product Innovation

Perhaps the most striking feature of TWI's product model is the stability and durability of its product offerings. All the major products offered in 1960 are still in place. Product innovations have been added to the existing portfolio only occasionally, and tend to run alongside established activities until assimilated into the mainstream. Examples include:

- Technology transfer, (which established an interface with SMEs)
- JoinIT® electronic knowledge trading (which changes the conventional expert service paradigm)
- The development of Granta Park (which changes both TWI's environment and income potential).

5.2 Participants in innovation: TWI stakeholders

TWI has a large number of stakeholders, as shown in Figure 5.1.

Fig. 5.1 TWI's stakeholders

The group with the principal commercial interest in innovation is the Industry Members, who comprise some 3500 separate industry sites in over 50 countries.

The influence of industry and professional members is exercised by means of TWI's governing Council, who oversee operations of the Executive via three Boards covering Research, Professional and Financial Affairs.

5.3 The Position of Innovation within TWI's Overall Business Model

The technology development cycle shown in Figure 4.2 is only one aspect of TWI's business model. The evolution of TWI's business over the last 55 years has resulted in series of complex and overlapping staff activities that meet the needs of stakeholders.

The technical focus for delivery of these activities is TWI's experts; staff who take responsibility for specific technical areas and who form the organisation's primary knowledge resource.

As expertise is TWI's primary resource, the availability and use of expert time is extremely important. As pointed out earlier, TWI has accumulated a large number of different types of activity that are delivered by its experts. All these activities are considered important to TWI's mission, but they confer different levels of benefit, both on TWI as the provider, and on TWI's customers as end users. Analysis of the value added by these activities, may be related to the volume of business transacted, yielding the schematic relationship shown in Figure 5.2.

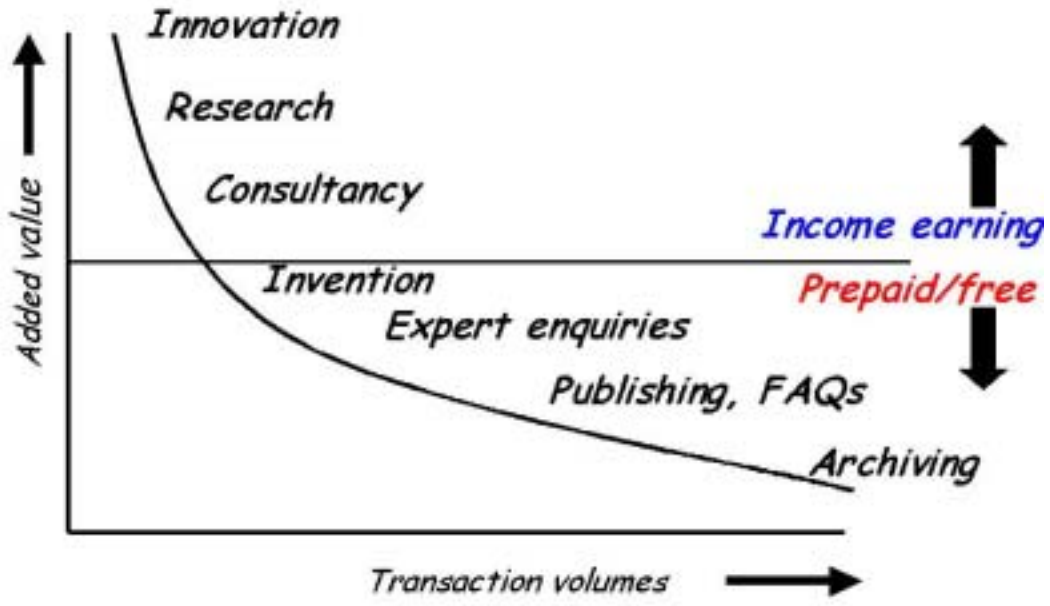


Fig. 5.2 Expert labour utilisation at TWI

The data that support this figure indicate a marked relationship between the income earning capacity of an activity and the added value that may be created in an end user. As an example, the DTI Assessment Unit analysis indicates the average end

user benefit from a simple phone call to TWI as £100, while TWI member responses show a one-off multiplier of x70 on contract research with x17 recurring benefits.

Innovation, when carried through to a commercial conclusion, confers the highest added value to all stakeholders. An example is Friction Stir Welding, which was invented in 1991 and now contributes several million pounds annually to TWI in the form of membership subscriptions, licenses, and contract income. However, TWI's revenues from this innovation are dwarfed by the industrial benefits experienced in several supply chains in the aerospace, automotive and construction sectors.

Figure 5.2 concentrates on the utilisation of expert time as a key organisational resource. It also shows a tension between income earning activities and prepaid/free services. The difference in transaction volumes is marked. Low added value activities have a natural tendency to absorb expert time, a trend supported by day-to-day pressure from members, as well as TWI's service culture and staff relationships with members. For these reasons, increases in income earning activity are surprisingly difficult to achieve.

5.4 Drivers for innovation

Stakeholder demand and staff technical initiative interact in driving TWI innovation activities. TWI industry members, who are the primary stakeholders for innovation, fall into three broad groups.

- Long-cycle innovation companies whose sectors are subject to close regulation and who have an overriding interest in structural integrity and safe operation of plant. This group includes oil and gas, energy and process plant companies. While they recognise the need for technical change, their ability to innovate is moderated by strong regulatory processes, and they tend to have a long innovation cycle.

- Rapid-cycle innovation organisations who are exposed to rapid market change and have a continual need to develop new products and services. Companies in the electronics, sensors, automotive, and healthcare sectors fall into this group, having an urgent and continuous dependence on material and process innovation to support their market position.

- In contrast to the two other groups, industries such as aerospace are a hybrid, being subject to long development cycles and high regulation, but having a marked dependence on technical innovation.

5.5 Patterns of innovation

The variation in innovation cycles among members is reflected in the innovation interests of TWI's Industry Groups and the invention activities of TWI Technology Departments. Structural integrity engineers and metallurgists (who largely work for clients in the long-cycle group) are mainly involved in incremental development and failure investigations. They have less opportunity (and perhaps inclination) for invention than staff in process technologies, who interact with rapid-cycle as well as slow-cycle customers. Structural integrity patents account for 10% of TWI's application portfolio, while metallurgy developments represent only 2% of the total.

The majority of these are in instrumentation, mechanical testing and non-destructive testing (NDT).

The profile of invention within TWI is also linked to the distribution of inventive behaviour among staff. Over the last thirty years, it is estimated that 10% of professionally qualified staff have filed patent applications, 7.9% have filed once, 1.6% have participated in 2-5 filings, while 0.5% have 6 or more applications in their name.

Because TWI's main reason (irrespective of commercial motivation) to file patent applications has always been to reflect member's interests, the patterns of filing reflect technology evolution in industry. Over the last ten years, patents have been centred on plastics, ceramics, coatings, composites, friction processes, and power beams. In each case, the groups involved in the innovation have included one or more individuals with a strong personal inclination to invent. Simple psychometric test results from TWI staff support this conclusion. (TWI has used Belbin team profiling analysis internally since 1994).

The importance of recognising and protecting intellectual property within TWI is reflected by a course on Intellectual Property Rights being included in the Graduate Induction Course, and current management training being targeted at facilitating internal communication and promotion of the exchange of ideas.

5.6 Corporate memory and the demographics of expertise

Having identified invention with individuals, it is worth noting the vulnerability of TWI and similar expert-based organisations to loss of skills and tacit knowledge when members of staff leave (cf. Scarborough, 1996). An illustration of the problem is TWI's coverage of stainless steel fabrication. A Best Practice Technology Guide, written in 1996 (Ginn 1996) had four authors, summarising their collected knowledge on the subject. None of the authors remain at TWI: two having retired, and two having died well before retirement. The total knowledge loss to the organisation was in excess of 100 expert years.

The models proposed by Winch in the ESRC Innovation Programme (Winch 2000) are relevant here, but the detailed measurement of expert competence is complex, going beyond academic qualifications and technical experience to include business skills and industrial credibility. TWI is continuing to examine this subject as part of its knowledge management effort. For the purposes of this report, attention will be

focused on overall demographic issues, rather than on the nature of the skills involved.

Recruitment policies have changed in recent years, to manage corporate age and experience profiles. There has been significant recruitment of experienced staff in addition to the more usual new graduates and doctorates. Figure 5.3 shows the age and service distribution for TWI graduate staff.

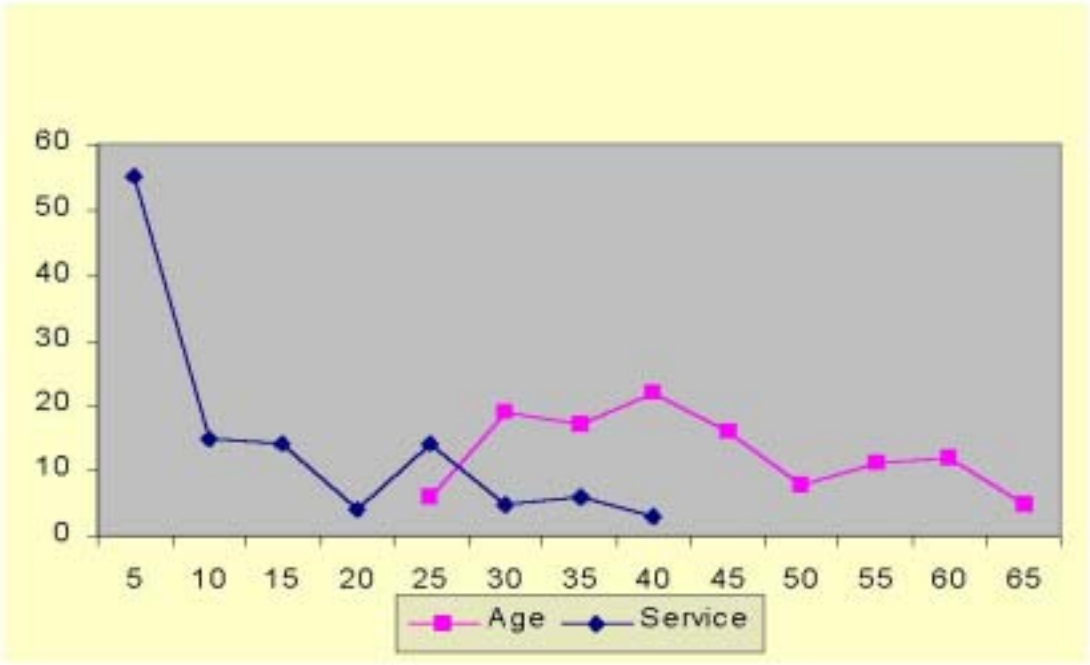


Fig. 5.3 Age and service distribution for TWI Graduate staff.

As might be expected, the age profile tapers off for both young and older staff, but the service duration plot is skewed to recently recruited staff. This indicates a policy of recruiting significant numbers of experienced graduate staff, who add their experience of technology, industry and business practice to the corporate knowledge pool.

5.7 Perception and Control of Innovation

Perceptions of invention and innovation within TWI tend to reflect the technology background, experience and personality of the staff involved. With highly self-motivated technical staff, there is always a tendency to concentrate on invention and push technology. This has been countered to some extent by extensive management training programmes and graduate induction courses over the last twelve years. Even so, control of technical enthusiasm without demotivating the staff involved remains a challenge to top management.

A generic view of innovation is now replacing the specific cycle shown in Figure 4.2. TWI currently operates a three-part innovation process that can be thought of as a pipeline containing a moving stream of ideas Figure 5.4.

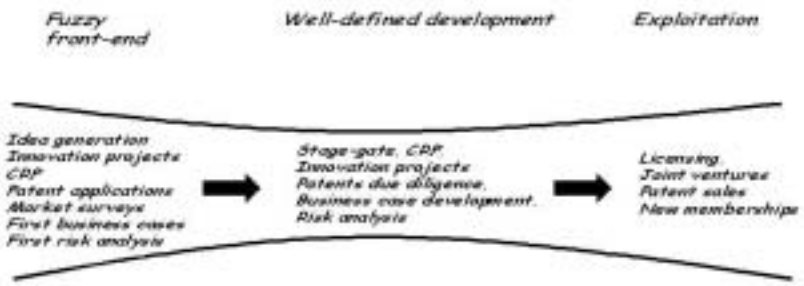


Fig. 5.4 TWI's innovation pipeline

The three phases in the pipeline have distinctive features that cope with the need to balance freedom and control. The first and third phases are less well defined than the well-structured central development sequence because the best course of action in a given case will depend on factors such as the perceived market size, estimated risk and required investment.

Inventor involvement is believed to be critical in maintaining enthusiasm for the innovation process, and originators of ideas are given the option of working on the development of that idea through the three phases.

Characteristics of the three phases are described in the following sections.

5.7.1 Invention

Invention resides at the "fuzzy front end" of the innovation pipeline: so-called because creative activities of this kind tend to resist formalisation. At this point in the innovation process, TWI's management is tolerant of a degree of 'anarchic' working. Activities in this area start with idea generation and then move into the first elements of the stage-gate process, which include initial TWI-funded pilot projects, innovation projects, Core Research Programme (CRP) projects, patent applications and the early stages of compiling a business case i.e. market survey and first risk analysis.

Structured approaches to idea generation are used at TWI, employing a series of creative tools as itemised in Figure 5.5.

Tools for Generating Ideas (Diverging)	Tools for Sorting an Selecting Ideas (Converging)
• Brainstorming • Brainwriting • Blending far and near • Concept Building • Infinite Possibility Generator • Ladder UP and Down • SCAMPER	• Hits, Votes or Rouletting • Clustering or Highlighting • Paired Comparison Analysis (PCA) • Advantages, Limitation, Overcoming Limitations • Sorting • Evaluation Matrix • Customer Jury

Fig. 5.5 Tools used at TWI for idea generation

However, many of the best ideas come from the combination of two previously unconnected pieces of information in the mind of a single individual, (Albert & Bradley, 1997. Nonaka, 1994.). TWI's experience is in line with these views: technical inventions usually arise from creative individuals operating in fertile environments, where either technology opportunity or market demand is strong. This suggests that matters of individual attitude and motivation, coupled with individual-group processes are likely to influence TWI's ability to invent and innovate.

After an idea has been generated, a route for development must be established and funding will be required. Early considerations will include first estimates of market size, intellectual property position and resource requirements. Initial views on patenting are taken during discussions with the appropriate Technology Group Manager and Intellectual Property Manager. In addition, it may be appropriate to apply for an internally funded Innovation Project to help to establish the technological feasibility of the idea.

5.7.2 The Stage-gate Sequence

TWI's stage-gate process, Figure 5.6, is designed to help innovators to bring new products and processes to market rapidly and successfully. The early stages in the stage-gate process are necessarily flexible, to generate a climate compatible with

the idea creation phase. In fact, the first stages very closely resemble the existing TWI mechanisms for the generation of ideas.

Once the feasibility of the new idea has been proven the requirements of the system become more rigorous and it is at this point that the decision to apply stage-gate or not is taken by the Directors. As the development progresses, the team involved in the process grows to provide all of the competencies required by the stage-gate process.

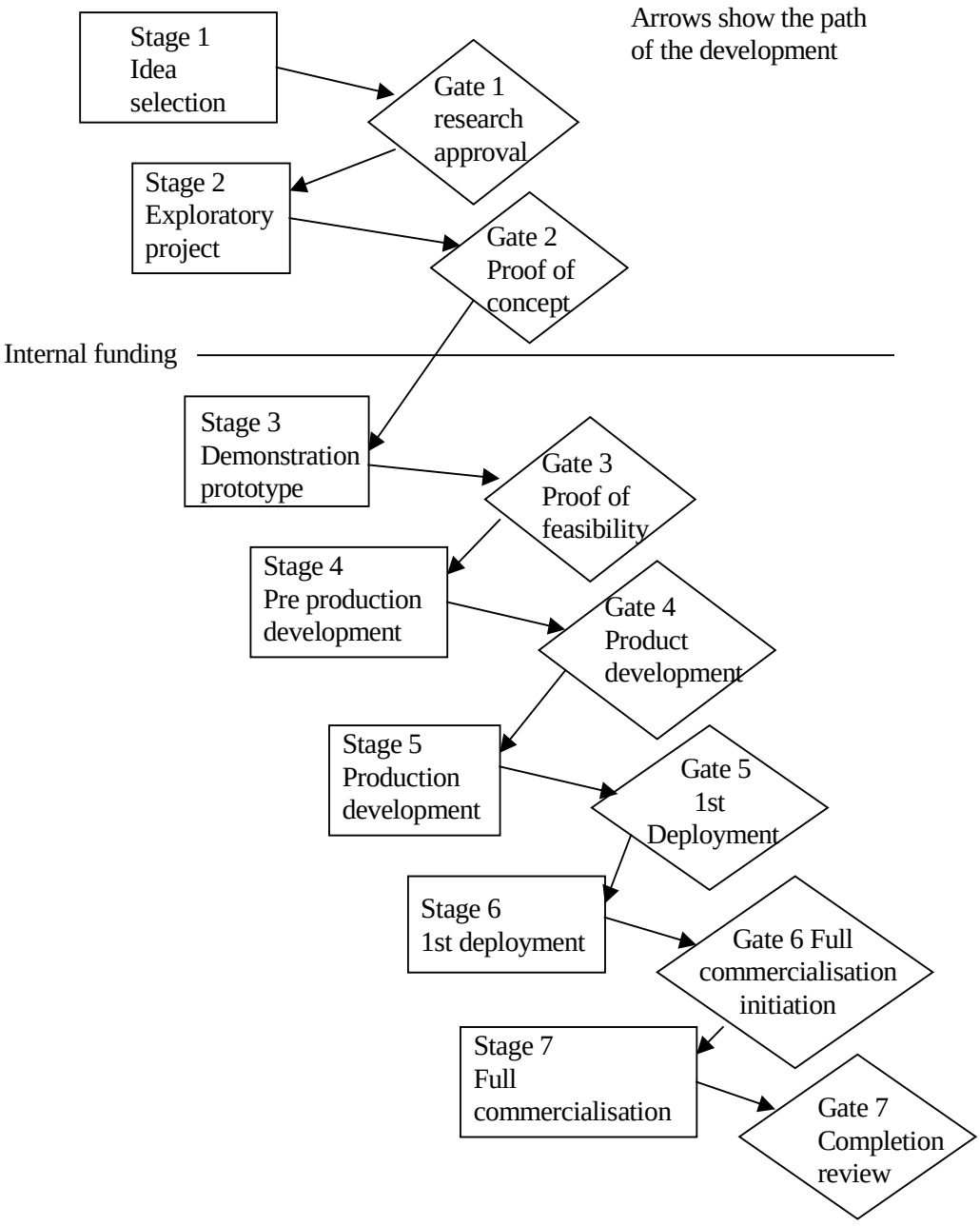


Fig. 5.6 Stage-gate innovation management sequence

The stage-gate sequence contains a predefined checklist to ensure all of the considerations required for a successful innovation have been addressed at the appropriate point in the development. Gates are points in the product development process where formal decisions must be made to go, kill, hold or recycle the

project. Gatekeepers, who are senior managers, use objective criteria to measure performance in line with pre-defined requirements of the gate.

Stage-gate ensures that business strategy formulation is supported by appropriate information at the right time in the innovation process. This optimises the use of TWI's resource for innovation.

5.7.3 Full exploitation phase

Part of the development process includes the generation of a business case so that the most appropriate commercial strategy is adopted to ensure the innovation meets current business objectives. Similarly, the organisation is open to using a range of financial mechanisms for the developments of ideas, again looking for the one which is most suitable for any particular development.

TWI has the following commercial options as exploitation mechanisms for its innovations.

- Projects (including single and group sponsored, and collaborative)
- Licensing of intellectual property (patents, trademarks, know-how etc)
- Equity in exploitation companies (owned as a whole, jointly owned, etc)
- Selling of intellectual property (outright or in divided shares)
- The sale of products (including hardware and software).

Enlarging TWI's technology portfolio increases its appeal to new industry sectors, and so an immediate business outcome of any innovation is often an enlargement (and sometimes stabilisation) of the membership base.

5.8 Environmental influences on innovation

In practice, the innovation process is subject to many environmental influences. For an RTO like TWI, these include.

- Availability of skilled human resources
- Availability of seed-funding for the early stages of the process
- Availability of suitable capital plant for carrying out the work
- Funding over a sufficiently long period to enable later stages of the process to be tackled
- Relationships with end-users who can exploit the innovation industrially.

5.8.1 Human resources

While human resources are clearly an issue, this is perhaps the one factor that can be solved once all other measures are satisfied, TWI has long experience of recruiting high level staff, and also works constructively with HEIs and member companies world-wide in collaborative technical developments. These networks allow it to lever significant technical resources, using projects and alliances to support innovation activities.

5.8.2 Seed funding

Currently, TWI sets aside a small percentage of internal, prepaid members funds to support new ideas to the point where they can be financed from other sources. The amounts available are limited, and the Director of Research oversees a strict

rationing process. The level of first-stage innovation that might be possible if funding was increased is not known, but is likely to be substantial. This raises the question of UK infrastructure and demonstrates a marked negative difference between UK public support and that provided in Germany and the USA. It is a policy issue needing urgent attention by the DTI and Treasury.

While venture capital is a potential source of funding for such developments, the loss of independence that might result during exploitation is a concern to TWI, with its significant membership stakeholding. Innovative approaches to the provision of capital for development will address this concern. These are likely to be provided by companies specifically targeting knowledge transfer organisations, such as E-SYNERGY.

5.8.3 Capital plant

Provision of leading edge capital equipment to support innovation is a continued challenge to TWI. As many innovations demand purpose-built kit, or significant customisation of as-supplied equipment, hiring space on external plant is seldom an option. A part solution to this problem is to obtain capital plant under favourable terms by a range of mechanisms, including those that rely on TWI's position as a showcase for commercial products. However this is not ideal and is another example of infrastructure failure by government in the UK compared with competitive countries. A support programme of public funds would be more effective in leveraging the economy than many of the present DTI initiatives.

5.8.4 Long-term funding

It is important that project management support is available long enough to permit realistic progress through the stage gate sequence. While it may be appropriate to involve potential end users at an early stage, there is a danger that innovation routes may deviate from the ideal to match short-term pressures. This tendency is countered by the discipline imposed by long term objectives. These comprehensive support facilities are in contrast to some proposals put to RDAs (Regional Development Agencies) which underestimate the complexity of real business incubation.

5.8.5 End-user relationships

TWI enjoys stable relations with the majority of its member companies. For this reason, end-user relations are usually cordial and constructive. The situation would be improved even more if the other stabilising factors were better developed.

5.9 Individuals, groups and innovation in practice

Storey's model of the innovation theories he found proposed by managers, Figure 5.7, indicates a variety of theories-in-use which apply across a range of companies.

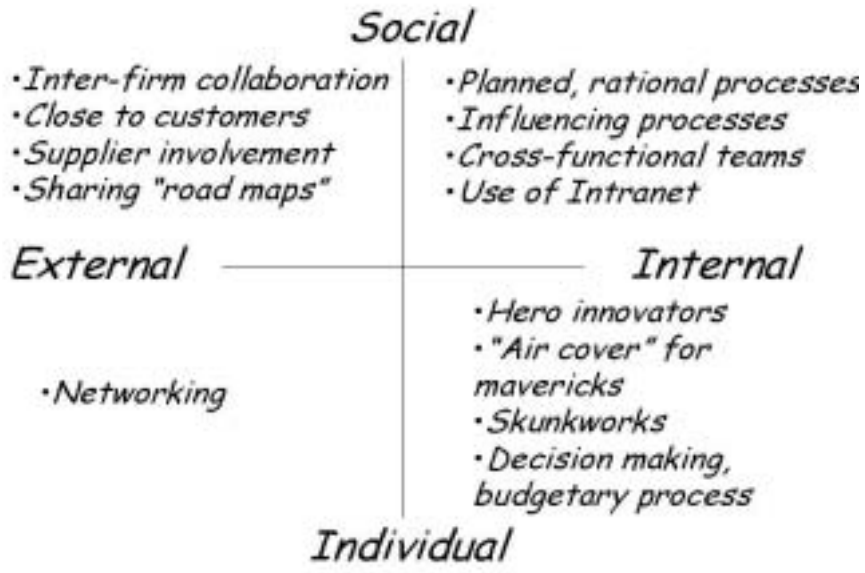


Fig. 5.7 Theories of Innovation (Storey 2000)

Interestingly, TWI staff recognise all these approaches, and discussion suggests that they co-exist within the organisation, being applied with local variants depending on circumstances, as shown in Figure 5.8.

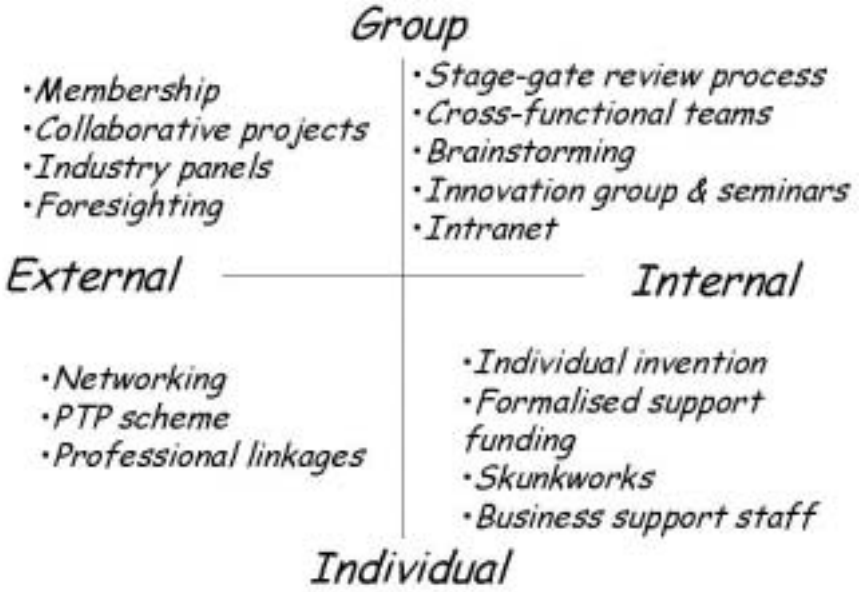


Fig. 5.8 Innovation practices at TWI

Although the choice of preferred approach in given circumstances is defined in theory, significant interactions between individuals and groups may result in

different behaviours in practice. A development of Storey's model appears appropriate, to express possible interactions between individual inventors, the "official" TWI innovation process, member companies and/or professional contacts.

Figure 5.9 expresses these possible relationships, starting from the proposition that idea generation is primarily an individual activity. If this is so, (and inspection of TWI patent records suggests it is, see section 5.5), then the path taken by a given idea will depend on the perception of the individual regarding the ease or otherwise of following different innovation routes. Also, as the development of an idea through the innovation process proceeds, different quadrants of the matrix may become relevant and a more complicated route for the development of an individual idea over time can be 'mapped' onto the matrix.

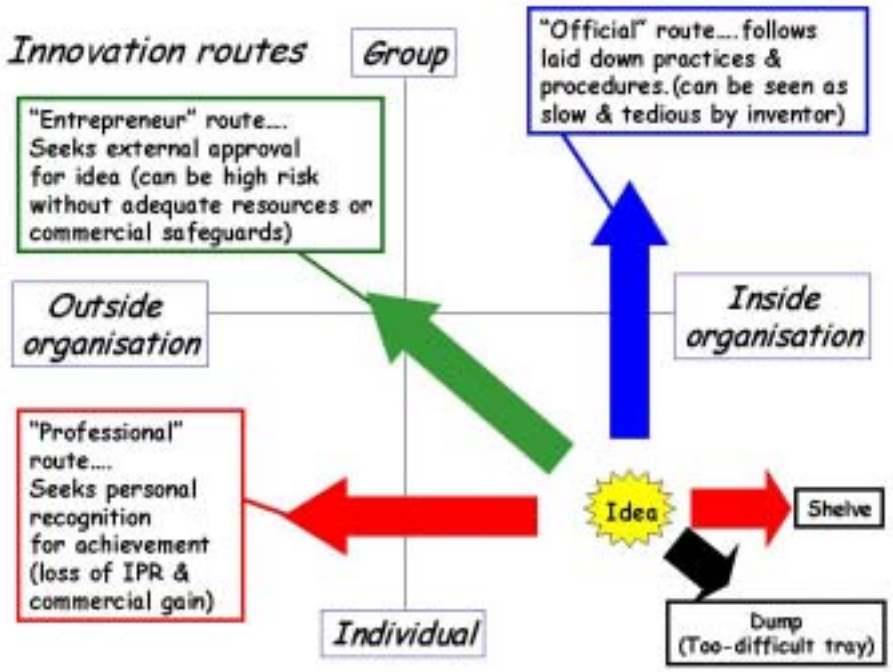


Fig. 5.9 Routes for handling ideas

Only some of the pathways shown in the figure are recognised within TWI.

- TWI has a good level of information regarding "official" innovation activities. The Management Information System (MIS) captures technical and financial information regarding ideas that follow the "official" route. Further

information regarding these processes is derived from the agendas of internal committees, the quality system and other project documentation.

- The "entrepreneur" route is also recognised as an "unofficial" way of gauging market interest in new technology areas. No information is available regarding the scale of this activity, although several examples of past (successful) entrepreneurial ventures can be cited. Acquiring external contract income and support for new ideas is a tempting (if risky) avenue for

staff with excellent member contacts and income budgets to meet. This route can pose a threat to the retention and development of IPR.

- The leakage of novel ideas through professional contacts or publication is known to have occurred at TWI in the past. Technical enthusiasm and lack of commercial awareness favours such loss of intellectual property. Future losses are being countered by business development and graduate induction training, and also by teaming business development staff with technical groups. An additional leakage route in this area would be via the Postgraduate Training Partnership Scheme with Cambridge University. This eventuality is covered by an IPR agreement with the university.

- The remaining options for new ideas (shelve or dump) are known to exist, and were cited in several discussions with TWI staff. No data are available regarding the scale of this practice, but it appears that increased emphasis on financial measures and productivity might be expected to exert an influence on the magnitude of these routes, as might overall organisational culture.

The potential loss of inventive ideas from experts is a serious strategic issue. If they are shelved or discarded via organisational processes, at least decisions are likely to match corporate objectives. If individuals drop ideas without bringing them into the corporate domain, there is no opportunity to consider expanding resources or using alternative exploitation methods.

A point of particular concern is that individuals may lack enthusiasm, or confidence in their creative abilities. It is possible that operational pressures may discourage creative behaviour in some cases, and the skewed distribution of patent applications among TWI staff may support such a conclusion.

In summary, the problem of idea loss is known to exist, but its scale is uncertain: for this reason, factors influencing individual motivation were considered in some detail.

5.10 Interaction of the individual with TWI's business process

The business process for innovation centres on developing an idea through an orderly sequence, as indicated by the Stage-Gate process, Figure 5.6. In practice,

the innovation process at a human level is more complex, demanding negotiation with existing groups in the internal corporate supply chain, Figure 5.10.

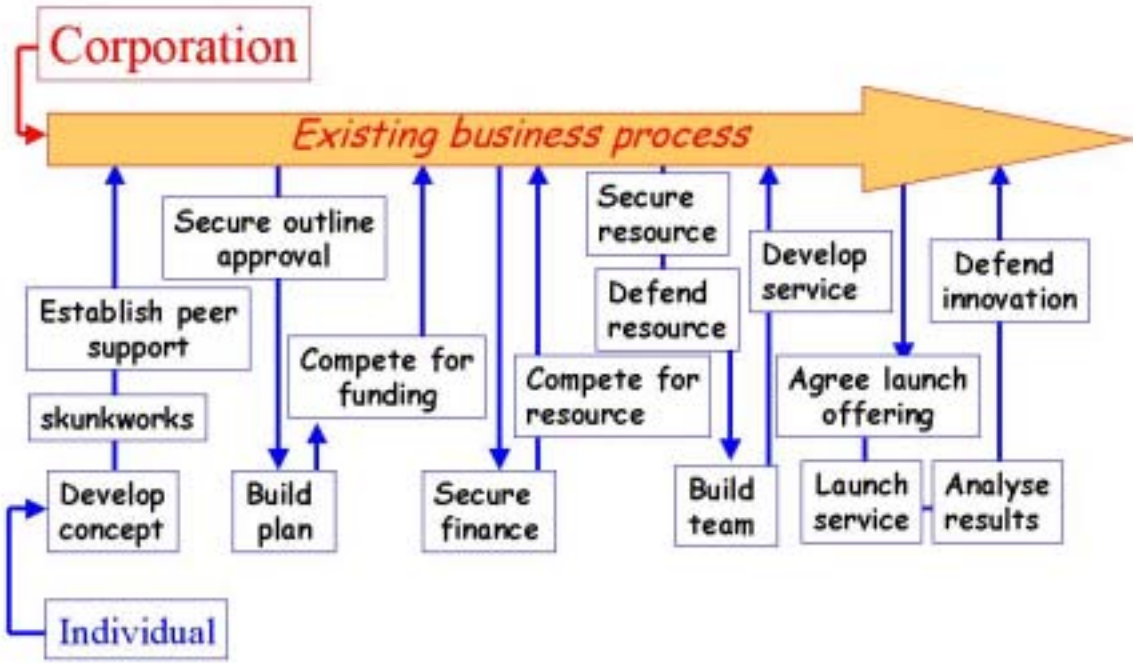

Corporation
Existing business process
Secure outline approval
Secure resource
Develop service
Defend innovation
Establish peer support
Defend resource
Compete for funding
Compete for resource
Agree launch offering
skunkworks
Develop concept
Build plan
Secure finance
Build team
Launch service
Analyse results
Individual

Fig. 5.10 The business processes involved in the development of an idea

Individuals who are competent at invention, may lack the networking and boundary spanning skills that are required for success, Figure 5.11.

Network Linking Skills	Boundary spanning skills
The ability to build relationships with a variety of individuals: • Interpersonal skills • Informational skills	The ability to communicate and operate in the range of organisational areas involved in innovation: • Communication skills- a variety of functional languages • Adaptability to different cultural contexts

Fig. 5.11 Skill clusters for networking competence (Steward 2000)

While the organisational system provides resources and personnel to aid an individual overcome internal hurdles, it must be remembered that innovative performance (i.e. the ease of traversing the obstacles) is related to the perspective of the individual who owns the initial idea (Guest 2000).

Walker, in the ESRC Innovation Programme study of innovation in housing associations (Walker 2000) raised the subject of unsurfaced issues in innovation. These consist not just of shared tacit assumptions, but also different viewpoints

that are not recognised or discussed. Similar differences were noted in Storey's work (Storey 2000).

McCosh, in the ESRC Innovation Programme study of 'Process Mapping to Measure Performance' (McCosh 2000), pointed out the difficulty of over-control of the innovation process. He also recognised the challenge of developing a diversified skill portfolio when resources are limited, and hinted at the division of companies into fast movers, who were able to resolve these issues, and average performers, who were not.

The relevance of these ideas to innovation at TWI was investigated using a simple model derived from the Blake and Mouton Grid (Blake & Mouton 1965). The Grid allows comparison of managerial styles in terms of two principal dimensions: concern for production and concern for people. TWI's inference from the Grid is that simple compromise between these conflicting issues does not generate optimal performance, but merely second division status, with corresponding modest financial performance, Figure 5.12. The challenge of the high commitment organisation (Lawler 1991, Pascale, 1997), is to find ways of satisfying both people development and production demands; not viewing these as alternatives.

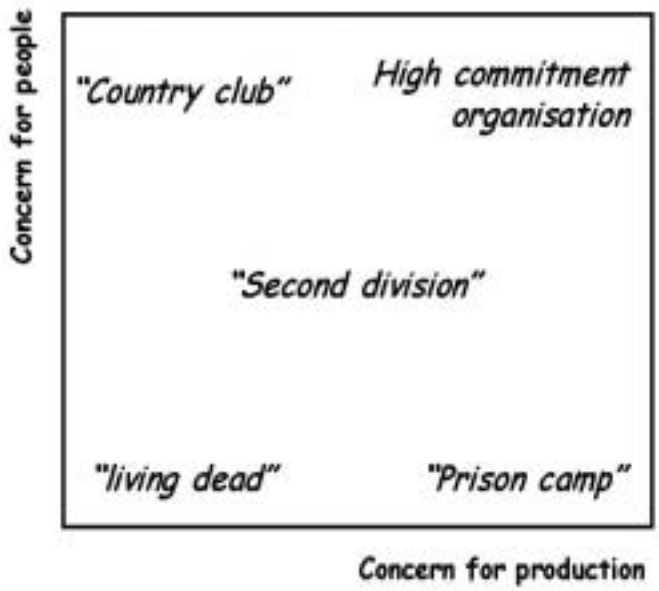


Fig 5.12 Management control grid (developed from Blake & Mouton, 1965)

Positive human resource practices have been shown to contribute to positive innovation attitudes and behaviours, (Guest, 2000), similarly, a concern for production is known to favour practical action, (McCosh, 2000), and might therefore be expected to encourage commercial exploitation of ideas. An elaboration of the Blake and Mouton analysis, Figure 5.13, suggests these ideas might be overlaid onto the earlier grid to provide insights into innovation behaviour.

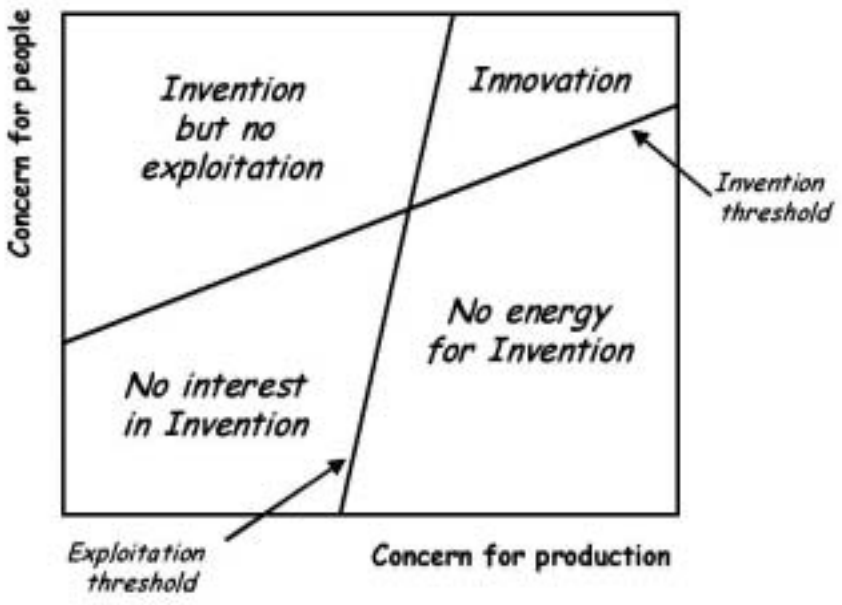


Fig 5.13 Innovation grid

The model as presented is schematic, but has been recognised and received support from all third parties contacted in this study. It suggests that innovation is only likely to be successful when concern for people is combined with (not balanced against) concern for production at sufficiently high levels to promote both invention and subsequent action. The following observations are relevant regarding the positioning of lines on the diagram.

i. The Invention threshold

The position of this line relates to an individual's innate capacity and drive to create new ideas. The gradient of the line is related to motivation, and is influenced by local culture ***as perceived by the individual***. The invention threshold is therefore a personal attribute, relating to abilities, and an individual's perceptions of situation. It is not susceptible to direct managerial control: in fact, command and control management approaches may suppress inventive behaviour by raising the invention threshold.

ii. The Exploitation threshold

This line expresses the organisation's ability to commercialise specific inventions.

Its position and gradient is a function of organisational policy, systems, culture and team coherence.

Even though the exact position of the lines is uncertain, experience at TWI supports the idea that the "innovation space" is both the smallest region and the most difficult to attain. Entering such a space and maintaining position demands

leadership and a strategic understanding of the need for a constructive relationship between the organisation and employees.

5.11 Individuals, Innovation and the Organisation

The above analysis suggests that successful innovation depends on the alignment between corporate and individual capabilities and goals. The "contract" involved goes beyond any written document, and may involve significant unsurfaced issues.

Unfortunately, common operational management often works against developing such a contract, as Morgan and Maddock found in their ESRC Innovation Programme study of innovation in the NHS, Figure 5.14.

Rhetoric (espoused behaviours)	**Reality** (behaviours in use)
Innovation promoted	Risk-takers punished
Talk quality	Reward & measure quantity
Talk strategy	Manage tactically & reactively
Talk flexibility	Watch staff timekeeping
Value training	Leave no time for it
Corporate vision	Manage operationally
Staff are individuals	Manage groups
Want openness	Hide realities

Fig. 5.14 Core conflicts in managing change (Morgan & Maddock, 2000)

The impact of such a situation within an RTO would be extremely serious. To guard against this, a series of corporate and individual competencies and behaviours may be proposed to link with espoused behaviours, thus encouraging operation in the innovation space, Figure 5.15.

Behaviours that support innovation	Organisation	Individual
Visionary leadership	Integrated view of innovation translated into practice by senior level example *Documented strategy*	Identification with demanding goals *Supported by effective corporate communications*
Innovation promoted	Verified innovation systems *Documented innovation policies & processes*	Qualifications and experience *Supported by a deliberate recruitment policy, early exposure to real industrial problems, and senior staff mentoring.*
Quality focus	Tolerance of failure *After-action reviews. Positive regard for individuals*	Understanding of risk *Understanding of research and commercial relevance of innovation*
Strategy implemented	Strategic perspective *Corporate strategy with cascaded plans*	Business acumen *Business development training*
Flexibility practiced	Understanding of emergence *Project & process reviews, willingness to alter targets. Cross-boundary collaboration*	Flexibility *Graduate induction, Multidisciplinary teamwork*
Training valued	Corporate Learning *Continuous capability reviews* *Conscious development of organisational intellectual capital*	Interest in personal development *Continuous professional development* *Awareness of personal intellectual capital*
Corporate vision shared	Clear and shared language *Corporate Plan, sub goals, cascaded communication and feedback*	Reasonableness *Teamworking skills, broad technical and commercial capability*
Staff recognised as individuals	Supportive environment & free communications *Mentoring. Business development champions.*	Trust & openness *Personal history, personality, relations with colleagues*

Openness practiced	*Open-door policies & informal access to senior staff. Conflict resolution* Incentives for performance *Appraisal reviews, Career progression, non-financial rewards*	Energetic *Enthusiasm for task & goals*

Fig. 5.15 Competencies and behaviours that support innovation

Achieving a capability across all these issues is very challenging. TWI's current tools to deal with this task include.

- The Corporate Plan, which is revised annually
- Cascaded appraisal targets for all staff using SMART objectives
- A Management Information and Communication System implemented on the corporate intranet
- A Knowledge Directory, linking TWI technical coverage to specific experts
- A Matrix structure combining business development and technical excellence responsibilities
- An IPR guide, outlining TWI's intellectual practice methods
- Quality systems to ISO 9001 and TickIT
- Application of 6-sigma quality methods to internal processes
- An Innovation guide, describing TWI's innovation strategy and methods
- Graduate development training for all new staff
- Business development training for all professional staff
- Prototype Communities of practice addressing specific innovation themes
- Idea generation training

Active recruitment reviews to develop corporate capabilities.
While these measures are probably far from optimal, they are a significant improvement on previous approaches, which lacked both clarity and focus.

A further rationalisation and integration of these processes is now possible by adding the following elements to the above list:

- Further development of communities of practice centred on innovation themes
- Economic methodologies and benefits analyses for existing innovations
- Measurement of invention and innovation capacity for the organisation
- Innovation capability and sensitivity analyses to base business cases
- Incentives for inventors and their host groups
- Intellectual capital analysis and valuation of intangible resources
- Training to create an understanding of innovation at both corporate and individual levels.

5.12 Summary of TWI's innovation situation

TWI fills a complex technical and commercial niche, employing a business model that confers considerable stability, but which denies access to conventional funding routes for innovation support. Application of ESRC Innovation Programme results to an analysis of TWI's operation has illuminated some of these issues. It has also

highlighted the importance of understanding the unwritten, but very real "contract" which underlies an individuals willingness to engage with official innovation procedures. The organisation has a number of mechanisms in place to address these issues, but it has been possible now to propose other measures and activities that may promote innovation by an increased number of staff.

6) Relevance of analysis to other RTOs

The benchmarking exercise targeted RTOs and other relevant organisations that represented different technological and industrial sectors, and had different business models. A presentation of the analysis of innovation management

described in sections 4 and 5 was made to each organisation, and then their individual concepts of, and approaches to, the management of innovation were discussed. In spite of the diversity of organisation, innovation was recognised as being vital in all cases in order to refresh their technical and commercial capability. At the qualitative level, the RTOs could identify with the models of innovation based on the analysis of TWI using the models and tool from the Innovation Programme. However, some fundamental differences could be observed. For example, The National Computing Centre (NCC) needs to innovate rapidly because of the fast changing industry in which it operates. CERAM has demands from both the traditional and modern ceramics industries which it must meet, and BHRG has a commercial driver to its innovative activity because of the business model under which it operates.

A quantitative method of comparing the innovative performance of different organisations was suggested as being an effective method of benchmarking RTOs. Possibilities for this included number of patents filed and level of license income. However, some reluctance was expressed in making this data available to other organisations. An alternative is to judge the overall performance from quantifiable indicators such as turnover, profit, and staff numbers over a number of years.

In spite of the interest in innovation and its stated importance, only one RTO provided any instruction or guidance to staff on the management of innovation (see section 6.1). This was regarded as an omission by several RTOs, and was seen as an area which needed addressing.

Financing of innovation was a topic raised by many RTOs. Ideas and inventions do not appear to be in short supply, but with limited internal resources potential developments are prioritised by RTOs, either by formal or informal processes, or by default. The alternative to internal funding is either commercial or government funding. Commercial funding is not usually accessible during the proving stage of a development. Today there is no support link between RTOs and government which is the result of DTI policy which is now directed to activities with lower multiplier potential in the UK economy.

Specific points from discussion with individual organisations are covered in the following sections.

6.1 BHRG

BHRG had a comprehensive approach to innovation management, possibly resulting from a CEO who was involved in the teaching of innovation management outside of the organisation. Specific points of note were.

- All ideas are vetted by a “blue skies” committee, who decide on the resources that are allocated to developing an idea. As resources are finite, ideas are sometimes shelved for future consideration. There is a clear understanding of the resources available for innovative activity.
- A clear feedback to inventors for the decisions of the blue skies committee is given.

- A senior member of staff is appointed to champion an idea through a stage-gate process of development. The senior members of staff will all have been involved in successful innovation in the past.
- Courses on innovation are given to staff.

6.2 Fraunhofer Institutes

Visits to two Fraunhofer Institutes in Germany were undertaken at the suggestion of the ESRC project awarding panel. The two institutes (Institut fur Laser Technik [ILT] and Institut Produktionstechnologie [IPT]) were selected because they are involved in similar technologies to TWI. Also, previous technical contacts and professional relationships meant that discussions would be open and frank.

The Fraunhofer model has often been used as a comparator for UK RTOs. Over 50 institutes are now operating under the umbrella Fraunhofer Gesellschaft. Each Institut has a significant level of autonomy and is linked to a university, with the Institut head also being a university professor. A typical funding breakdown is 33% central, 33% Government and EU, and 33% industrial. The two institutes visited had grown rapidly over the last 15 years. ILT with 250 staff wishes to grow further, but is restricted by space in its building. The normal route for funding buildings for Fraunhofer Institutes is the state government, but there is no money available from this route for ILT. IPT is more stable in its numbers with ~160 staff.

Discussions regarding the management of innovation at these institutes highlighted the following points of comparison and contrast.

- Innovation was considered an integral part of the institutes' activities and crucial to their continuing success.
- Fraunhofer Institutes have a relatively small number of permanent staff, with the majority of people employed on short term contracts. This latter group may be post-graduate or post-doctorate. Typical contracts are five year but can extend to eight years. Other than administration staff, IPT has only seven permanent staff. These are the senior technical staff. ILT has a larger number of permanent staff (~60) but still the majority of technical staff are on short term contracts. Both organisations viewed this deliberate turnover of staff as having positive and negative effects on innovation.
- The technical direction of the institutes and hence their innovative activity is more centrally and formally controlled than was apparent for UK RTOs. For

example, the senior staff at ILT meet every week. Limited time is spent on administrative matters, with the main focus being technical.

- This centralised control of technical direction results in the ability to take bold strategic decisions. In the last two years, ILT has withdrawn from an activity that formed a major part of its operation since it was formed, and started work in two areas where it had no previous expertise although they are both promising areas for laser use.
- Fast-track funding is available to Fraunhofer Institutes for proving new ideas (cf. UK situation above). This funding (up to 150,000DM) is available from the Fraunhofer Gesellschaft within two weeks of a successful application being made and these funds are due largely from the block grant to the Fraunhofer Gesellschaft from the equivalent of the DTI - Minister for Science.

- Successful patent applications result in a small payment being made to the inventor. This amounted to few hundred pounds, but the recognition was viewed as being more important then the actual monetary award.
- Significant interest was expressed in knowledge management as an enabler of innovative activity. This is perhaps not surprising with the continuous turnover of staff discussed above.

6.3 Institute of Management

The discussions held with the Institute of Management covered innovation management of their own staff, and that of their member companies which are involved in all aspects of business life. There was a general acceptance of the analyses and models presented, and the following points of particular resonance.

- There are wide differences in perceptions and reality in innovation management (cf. Morgan and Maddock), among managers.
- There is a need for accepted definitions of the terminology used in innovation management (cf. Overall summary of ESRC programme in Appendix A).
- Knowledge management is a key factor if an organisation is to innovate effectively. Although this is becoming increasingly recognised, ways of dealing with this challenge are still in the development stage.
- There is a need for training in innovation management at all levels in organisations.

The latter point has led to joint work being planned between the Institute of Management and TWI, another unique benefit arising from the ESRC/AIRTO Award Scheme.

6.4 St Johns Innovation Centre

St. John's Innovation Centre provides accommodation and facilities for new high-tech companies in the Cambridge area. The expectation is that companies will grow to a critical mass, and then move into their own commercial premises. Discussion was held with the Director of the Centre, who has been involved in the promotion of technology based companies in the Cambridge area for 30 years.

Comparison between the innovation processes in start–up companies and established companies were made, where the increasing complexity of the

management process was recognised as the organisation loses its focus on an individual development. The analyses and models developed in the current project were thought to be of more value than previous “more academic” studies in helping start-up companies to understand the innovation process that they would be involved with as they mature. There was a feeling that this research highlighted usefully the complex nature of business incubation.

6.5 Other organisations

Specific points of discussion with other organisations were as follows.

- The leakage of ideas and information from research staff is a recognised problem and must be addressed (SINTEF, Norway, cf. Fig. 5.9).
- Venturing is the theme of the "2000s" to link innovation in the knowledge trader and their commercial customers (Leuven Research and Development, Holland).
- Customers for innovation are generally small companies at the start of a technology, and large companies in the "post dominant product/process architecture phase". IPR and joint ventures are more likely to be associated with the first of these, which is also a more risky stage (Leuven Research and Development, Holland).
- Organisation culture to allow the exploitation of individual and collective talents and skills is crucial to effective innovation management. This management should actively seek to minimise the building of physical and organisational barriers to innovation (Scientific Generics).
- Rewards for all stakeholders involved in successful innovation are an important part of innovation management (Scientific Generics and SINTEF, Norway).
- Formal and informal screening of ideas is important in the early stages of innovation management, particularly by peer groups. This should cover both technical and commercial prospects of ideas (Scientific Generics and SINTEF, Norway).

7) Discussion

TWI and the RTOs used for comparison recognise innovation as an important part of their activity. The mechanisms for dealing with innovation were found to be developed to a greater or lesser extent with most emphasis on the procedural aspects such as strategy, IPR management and the control of funding. However, there was found to be a common interest in a better understanding of all aspects of innovation both at the managerial and operational levels, and in the introduction of measures to enhance innovative performance.

This interest in developing a better understanding of innovation in AIRTO members can be addressed by the application of the results of the Innovation Programme, with the additional benefit of the credibility given to the analyses, concepts and

models by the strong academic basis. The projects allow the fundamentals of the subject such as scope and language to be identified, as well as basic mechanisms and intangible influences.

The results of the Innovation Programme and their interpretation have shown that innovative performance is linked to, and influenced by, many aspects of an AIRTO members' operation. Viewed holistically, leadership and strategy are vital to the achievement of a strong innovative performance, but attention to the detail of individual factors is also important. These individual factors can be practical aspects of the management regime under which an organisation operates, or more esoteric concerns.

Financial resources to fund the proving of concepts and the purchase of equipment is an example of the practical aspects that can restrict innovation in knowledge trading companies. The limited financial resources from within their own organisation means that many AIRTO members seek public sources of funding to develop or prove ideas before commercial funding can be obtained. The bureaucracy involved in securing this funding often results in substantial delays. These delays affect enthusiasm, commercial potential and the securing of IPR. A fast-track route to modest levels of early stage funding, such as that found within the Fraunhofer organisation, was considered to be crucial to improving innovative performance by the UK. Similarly, AIRTO members involved in capital intensive areas look for mechanisms that allow them to keep their equipment up to date. This could involve the funding of longer-term projects by public contracts (as used in the USA) so that the equipment can be amortised in the project duration, or the direct funding of capital equipment by government (which happens for universities in the UK, but not for knowledge transfer companies).

The scale of AIRTO member innovation activities is not solely constrained by available resources but also by conflict between individual and corporate interests. Traditional management oscillation between concern for people and concern for production may limit an organisation's ability to harness motivation, creativity and innovation potential. Unless these issues are recognised and tackled by conscious management processes, there is a danger that new ideas may be lost which also means loss of the multiplier effect on the performance of the UK economy.

AIRTO members are knowledge-based organisations. As such they depend on their experts as a prime resource. They are particularly vulnerable to corporate memory loss, and the management of corporate intellectual capital is a key strategic tool. Although advanced communications may help improve delivery efficiency, the position of the expert as the prime source of customer service and invention is as yet unchallenged. The knowledge-driven economy still lacks a trading infrastructure.

Because AIRTO members occupy the middle ground between academia and industry, they are well positioned to undertake innovation activities. Their services are commercially valid, as evidenced by their continued support from industry without public finance, but the question of their overall capacity for innovation remains. It appears possible that AIRTO member innovation potential is diluted by other financial demands. That there are opportunities for improving the business model, but these require a deeper understanding in government for an integrated

market infrastructure which includes industry, knowledge transfer companies, academia and government programmes. The concept of a network of partners is absent in present policy.

A fundamental issue in RTO history is limited growth, even though their markets have developed, diversified and globalised. RTO dependence on individual experts, both to sell and deliver services means that their business processes are essentially people-limited: they usually only increase revenues by increasing expert headcount. The nature of their expert-centred business models suggests that as RTOs grow, they tend to accumulate mission-driven prepaid services that set limits to expansion. If conventional growth is problematic, other means must be sought to

deliver increased levels of benefit to their clients. Many of the “new” AIRTO members which come from the private sector indicate the way forward.

Future expansion may be sought via networking and leverage using external resources (e.g. partnership with universities). Also by exploitation of other income sources such as licensing, spin-offs (creating new businesses), and non-technical investments (science parks etc.). Of these mechanisms, income from technical innovation activities is particularly attractive. It provides win-win benefits, both to the AIRTO member (in the form of license and other income), and to the customer (in the form of new processes and products), both of which contribute to enhanced dynamic in the economy.

TWI has already implemented measures that facilitate innovation processes, and will continue to improve its innovation strategy. Improvement will demand increased linkage of available systems, and importation of other methods highlighted in the Innovation Programme and in discussion with other organisations consulted in this study. The work reported in this study demonstrates the business benefit to be derived from networking ideas between academic research and applied research in a value-adding knowledge transfer company. In recent years this has been a neglected area in public policy. This work sets out to stimulate change in that policy defect.

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Appendix A:

The ESRC Innovation Programme

An Overview of the Innovation Research Programme

By Dr Fiona Steele
ESRC Programme Manager

Innovation – the successful exploitation of new ideas – is widely acknowledged as the key to sustained competitiveness. The ESRC made this its first priority theme in response to the UK Government's 1993 'Realising our Potential' and subsequent 'Competitiveness White Papers', and especially that aspect concerned with the application of new techniques and ways of working that improve the effectiveness of individuals and organisations. Accordingly it initiated a portfolio of innovation-related activities, including the Innovation Programme, designed to run to end-September 2000, which has encompassed 25 research projects undertaken by academic teams drawn from a range of disciplines and geographic locations.

The Innovation Programme was commissioned in two phases. The first, launched in September 1995, covered the role of innovative management in the achievement of sustained improvement in the bottom-line performance of commercial and industrial businesses. In particular it was designed to home- in on the human and organisational processes and conditions that contribute to this, and it encompassed a range of interests – small and large company concerns, sectoral and cross-sectoral issues, and national and international perspectives.

The second phase, which got off the ground from August 1996 onwards and extended its remit to cover both private and public sectors, continued the same overall theme but put even greater emphasis on the human element. It was uniquely set against a 'wish-list' of research questions canvassed from practitioners which included:

- the organisational implications of managing change, especially increasing attention to process rather than function and new forms of project management
- the balance between teamworking and individual commitment, especially with regard to creativity
- the implications of downsizing, flatter organisations and flexible workforce policies on career structures and human motivation

- the linkage of top management goals and change management at the operational level
- the human and social dynamics of creating truly customer-led business processes.

This wish-list was subsequently regularly refined over the life of the Programme in order to inform the progress of the research; and while it has remained broadly valid over this period, its emphasis has shifted towards market and people-related issues at the expense of business processes.

The Findings

Mindful of the Programme objectives, as well as defining and describing the 'what is' of management practices relating to innovation, the research teams have been encouraged to draw out from their specific analyses what might be considered as 'current best practice' in relation to achieving sustained competitive advantage through innovation. While such practices may not necessarily be innovative in themselves, their application in a new context is, and they are sufficiently generic to be applicable across both the private and public sectors and the range of sub-sectors within these. This overview summarises the key practices and capabilities identified by the Programme researchers as contributing to success (references in brackets relate to source projects); but before doing so, it should be noted that there is no single prescription for successful innovation, and that organisations will need to vary the recipes they adopt, mixing and matching the ingredients as circumstances dictate. Innovation is a dynamic process but the following practices will hopefully provide readers with a helpful template for action. It may also be useful to preface the ingredients by suggesting a number of definitions of innovation which have been applied in the research.

A 'Taxonomy' of Innovation

At a macro-level:

- 'total' involving discontinuous change both new to the organisation and serving a new customer/user
- 'expansionary' involving an existing product/service applied to a new customer/user
- 'evolutionary' involving a new product/service to an existing customer/user
- 'developmental' or 'incremental' involving a modified product/service to an existing customer/user.

At a micro-level:

- 'domain' involving developments in one area of expertise
- 'boundary' involving innovations across boundaries between specialisms
- 'contextual' involving new understanding of how changing circumstances affect the nature of particular activities.

(Blackler, Walker)

Key Practices and Capabilities for Successful Innovation

Strong Visionary Leadership

- establish a culture and climate in which innovation can flourish at all levels in the organisation, and encourage free and open debate
- demonstrate strong networking skills to engage internal and external stakeholders and build supportive relationships rather than tight controls

- show a willingness to be flexible about timetables and performance outcomes while setting priorities and goals – building and refreshing cultural capital is as important to competitiveness as economic calculations
- encourage effective and open debate about organisational goals
- engender trust and inculcate shared perceptions and open-ness to negotiation and change.

(Anderson, Morgan/Maddock, Pettigrew, Storey, Tann, Thompson [P], Walker, Wilson)

Organisational Structures and Business Processes to Support Innovation

- develop partnerships and alliances with customers and suppliers and aim for a longer-term perspective in so doing, and consider collaborative partnerships or outsourcing in areas such as R&D to leverage knowledge
- consider the introduction of virtual teamworking across the supply chain, and the introduction of specialist 'guest' workers to operate inside customers and suppliers
- follow the practice of high performing companies in simultaneously combining, in carefully aligned and complementary sets, several related organisational innovations such as:
  - changing structures (decentralising, delayering, project forms of organising)
  - changing processes (communicating horizontally and vertically, investing in information technology, practising new human resource policies)
  - changing boundaries (downsizing, outsourcing, developing strategic alliances)
- moving ahead on a single or only a few fronts can have negative effects
- create strong cross-functional networks and multifunctional, multidisciplinary project teams, but do not replace hierarchies by networks entirely as accountability is needed via a vertical command structure – successful diffusion of change requires that action moves from specific projects to durable innovation alliances between organisational functions and interests which must be continually reinforced
- create teams that are focused, specially formulated for the tasks and which achieve synergies via networking and knowledge sharing
- consider the application of Hoshin Kanri – a step-by-step planning, implementation and review process for managed change

- pre-estimate and pre-quantify competitive advantage gains from major capital investments as well as assessing criteria associated with cost, speed and reliability
- introduce high commitment human resource policies which see people as an investment rather than a cost, for example:
  - flexible employment contracts as the type of contract is not a strong predictor of innovative performance; rather what is mutually agreeable between employee and employer works best in encouraging innovative behaviour
  - involving employees in their job design and development and in problem solving, and granting greater autonomy to deliver
  - introducing reward systems which offer wider recognition mechanisms, such as public/peer acclaim and share options, as well as a straight monetary transaction

- allow some organisational slack and flexibility in order to encourage experimentation

- introduce performance indicators devised from the above and associate them strongly with the innovation message, bearing in mind that success is time and context dependent.

(Anderson, Barlow, Coombs, Fransman, Garnsey, Guest, Knights, McCosh, Morgan/Maddock, Pettigrew, Quintas, Roper, Slack, Thompson (P), Wilson, Witcher)

Competencies

- ensure a balanced management capability which thinks and acts holistically, and offers an increased capacity and willingness to explain and justify apparently contradictory tendencies in the organisation
- strengthen cultural change by compelling managers to reinvent themselves, delegating to wider layers and promoting changes in values, and embed them in networks with the purpose of improving performance, learning and innovation, and making multi-functional teamworking and industrial relations mutually compatible
- innovative managers need to manage the tension between the conflicting needs of being realistic but also far-sighted, being in control but also flexible, being trustworthy but able to take difficult decisions, making decisions while consulting others, and taking advice while being the acknowledged 'expert'
- develop the boundary spanning skills of managers through providing experience of different functions, and networking skills through close integration of management training, career mobility, and multi and in-company expertise
- think knowledge management rather than people management by engaging employees in learning cycles in which they can question, consider, communicate, model, improve and reconstruct ideas, and ensure that individual learning is properly integrated into organisational activities.

(Blackler, Pettigrew, Steward, Tann, Thompson (P))

Tools and Techniques

This review concludes with a summary of tools and techniques developed by the researchers to assist managers with the implementation of some of the key practices identified.

- 'Virtual Team Methodology Toolbox', web-based and comprising cost benefit analysis, video conferencing and readiness assessment tools designed to help companies implement effective virtual teamworking (Anderson)
- 'Knowledge Management Audit Tool' providing companies with a list of questions about knowledge management which can be used to do a basic 'health-check' identifying those areas where knowledge management for innovation is falling below desirable performance levels, and suggesting ways to address those shortfalls (Coombs)

- ‘User-led Innovation Model’ of management processes to capture and implement service users’ ideas for the delivery of improved services by local government organisations (Joyce)
- ‘SCRaP Analysis’ a business process model to analyse process maps pre and post the introduction of a major capital investment in order to assess whether the investment is likely to improve the Speed of service and Cost to customers, the Reliability of the product or service, and the Preparedness of the company to cope with new challenges (McCosh)
- ‘Guest Engineer Taxonomy’ defining the boundaries for typecasting guest engineers, identifying the strategic and operational structures to support their effective use, and offering guidelines for the attributes which make for a successful relationship (Slack)
- ‘Computer-aided Visioning Tool’ to prepare managers for major change and comprising a core generic model calibrated to the situation experienced by a given company at a macro level, user interfaces to enable post-change managers to manage the future virtual company, and an interrogatory interface to capture the change initiators’ expectations of the new enterprise (Winch)
- ‘Simulator for Innovation’ a multi-media interactive educational CD-ROM supported by a user manual which enables players to experience two distinct organisational cultures, one embodying all the attributes necessary to promote a climate conclusive to innovation and the other antithetical to innovation, and thus, by players making decisions themselves to achieve a desired outcome, to achieve a much better feel for key issues than from a traditional training session. (Young/Kaye)

Project List

1) **Towards Positive Partnering: Managing Client-Supplier Relations in Construction**
Professor James Barlow, University of Westminster

2) **Innovation Processes in High Technology Organisations**
Professor Frank Blackler, University of Lancaster

3) **Management in Knowledge-Intensive Organisations**
Professor Rod Coombs, CRIC, Manchester

4) **The Innovative Management of Innovation in British Companies: An International Comparative Study**
Professor Martin Fransman, University of Edinburgh

5) **Innovation Management in Small High-Tech Firms: Building on Experience**
Dr Elizabeth Garnsey, University of Cambridge

6) **User-Led Innovation in Local Government**
Professor Paul Joyce, University of North London

7) **Management Innovation in the National Health Service**
Glenn Morgan, University of Manchester

8) **Strategic and Organisational Innovations and Irish Small Firm Performance**
Dr Stephen Roper, Northern Ireland Economic Research Centre

9) **The Organisation of External Resources through Guest Engineering**
Professor Nigel Slack, University of Warwick

10) **Networks of Innovation Managers: The Paths of Experience and Education**
Dr Fred Steward, Aston University

11) **Innovation Management in Single and Related Product Companies**
Professor Jennifer Tann, University of Birmingham

12) **The Manufacturing of Workplace Innovation in the Scottish Spirits Industry**
Professor Paul Thompson, University of Edinburgh

13) **The Use of Hoshin Kanri as a Planning Tool to Implement and Align Strategy in Operations**
Dr Barry Witcher, University of East Anglia

14) **Simulator for Innovation**
Dr Barbara Young, Building Research Establishment

15) **The Introduction of Virtual Teamworking in the Automotive Supply Chain**
Professor Anne Anderson, University of Glasgow

16) **The Impact of New Forms of Employment Contract on Motivation and Innovation**
Professor David Guest, Birbeck College

17) **The Implementation of Business Process Re-Engineering (BPR) in Financial Services**
Professor David Knights, University of Keele

18) **Business Process Contexts for Technology Investment and Competitive Advantage**
Professor Andrew McCosh, University of Edinburgh

19) **The New Internal Network Organisation: Process and Performance**
Professor Andrew Pettigrew, University of Warwick

20) **Management of Intellectual Capital for Innovation: Individuals and Organisations**
Professor Paul Quintas, The Open University

21) **Managing to Innovate: A Comparison between the Perceptions of the Senior Management Team and those of Operational Managers**
Professor John Storey, The Open University

22) **Innovation and Reward**
Marc Thompson, Templeton College, Oxford

23) **Organisational Change in the Housing Association Movement**
Dr Richard Walker, University of Cardiff

24) **Developing Innovation and Creative Teams: An Empirical Study of Principles and Performance**
Professor David Wilson, Warwick University

25) **Computer-Aided Visioning in Preparation for Fundamental Industry Change**
Professor Graham Winch, University of Plymouth

Description of AIRTO

AIRTO is a network of the United Kingdom's independent research and technology organisations and promotes their role in strengthening industrial performance through consultancy, design, information management, knowledge transfer, research and development, skills provision, technology transfer and training.

AIRTO members are quality- and value-adding companies with a track record of success in knowledge transfer. They are driven by the desire for customer satisfaction and profitable success in a competitive market place.

AIRTO provides a point of contact between UK independent research and technology companies and government agencies, industry bodies and the European Community. It co-ordinates the views of its members and, by representing these to industry and government it provides policy leadership in the knowledge trading sector.

With some fifty member companies having between them a total turnover approaching £1 billion, AIRTO embraces a major portion of the growing industrial R&D effort of the UK. Members' activities span a wide range of disciplines from life sciences to engineering. Their work includes consultancy, managed fundamental research, contract research, developing and designing innovative products or processes, instrumentation, testing and certification, programmes of best practice, and techno-economic consultancy. Most run comprehensive information services, conferences and seminars as part of the process for knowledge acquisition and dissemination. Many organise joint ventures including venture capital investment programmes. The majority trade in the global market place.

Recent AIRTO Policy Papers are listed below.

2001/1 The contribution of Faraday Partnerships to growth in innovation intensity in the UK economy.

2000/4 AIRTO response to OST consultation on research in Europe after Framework 5.

2000/3 Increasing UK innovation intensity and the solution to the problem of knowledge transfer to business enterprise.

2000/2 AIRTO response to the DTI proposal for a network of regional centres for manufacturing excellence and productivity.

2000/1 Summary of AIRTO recommendations for a Science and Innovation Policy.

99/1 Encouraging people to collaborate to compete: Proposal for implementation of a Competitiveness White Paper vision – AIRTO VIRTUAL.

98/1 The PTP Scheme Achievements, lessons and recommendation for its continuation.

List of Members

Advantica Technologies Limited	Advantica
Advanced Manufacturing Technology Research Institute	AMTRI
Aircraft Research Association Ltd	ARA
BLC Leather Technology Centre	BLC
British Maritime Technology Ltd	BMT
Building Research Establishment	BRE
Brewing Research International	BRI
The Building Services Research & Information Association	BSRIA
British Textile Technology Group	BTTG
Campden & Chorleywood Food Research Association	CCFRA
British Ceramic Research Ltd	CERAM
Consignia	Consignia
Construction Industry Research & Information Association	CIRIA
The Central Laboratory of the Research Councils	CLRC
CRL – The Innovation Centre	CRL
ERA Technology Ltd	ERA
FIRA International Ltd	FIRA
HR Wallingford Group Ltd	HR
Inspectorate plc	Inspectorate
Leatherhead Food Research Association	LFRA
LGC	LGC
Materials Engineering Research Laboratory Ltd	MERL
The Motor Industry Research Association	MIRA
Mineral Industry Research Organisation	MIRO
The Motor Insurance Repair Research Centre	MIRRC
The National Computing Centre Ltd	NCC
National Physical Laboratory	NPL
Pera Group	PERA
Pira International	PIRA
The Paint Research Association	PRA
RAPRA Technology Ltd	RAPRA
SATRA Technology Centre	SATRA
The Steel Construction Institute	SCI
The Scotch Whisky Research Institute	SWRI
Sira Ltd	SIRA
Smith Institute	Smith Institute

The Sports Turf Research Institute	STRI
TNO BIBRA International Ltd	TNO BIBRA
TRADA Technology Ltd	TRADA
Transport Research Laboratory	TRL
TRW Technical Centre	TRW
TWI Limited	TWI

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