TECHNOLOGY MANAGEMENT PROCESS FRAMEWORK

Ikura Yamamoto, Darminto Pujotomo

Abstract

The effective management of technology as a source of competitive advantage is of vital importance for many organizations. It is necessary to understand, communicate and integrate technology strategy with marketing, financial, operations and human resource strategies. This is of particular importance when one considers the increasing cost, pace and complexity of technology developments, combined with shortening product life cycles. A five process model provides a framework within which technology management activities can be understood: identification, selection, acquisition, exploitation and protection. Based on this model, a technology management assessment procedure has been developed, using an ``action research'' approach. This paper presents an industrial case study describing the first full application of the procedure within a high-volume manufacturing business. The impact of applying the procedure is assessed in terms of benefits to the participating business, together with improvements to the assessment procedure itself, in the context of the action research framework.

Keyword: *Technology, Strategy, Management, Assessment*

1. Background

The impact of technology as a source of competitive advantage for manufacturing industries is widely accepted by practitioners, governments and academics. In order to realize this competitive advantage, it is vital to understand both the specific technologies, and the ways in which organizations can best manage technology. These issues are of increasing importance as the pace of technology development and its complexity increase.

The rising level of activity in the area of technology management studies is an indication of these trends. For instance, Clarke and Reavley (1993) provide a bibliography of published papers in the area of science and technology management, including over 10,000 references, up from 3,000 in 1981. As well as papers, a large number of reference books have been published, which provide greater access to technology management issues for industrialists and students (for example, Gaynor, 1996; Burgelman et al., 1996; Lowe, 1995; Dussauge et al., 1994; Steele, 1989). However, no particular textbook or approach to technology management has achieved wide acceptance. For instance, the technology management ``handbook'' edited by Gaynor (1996) comprises a collection of disparate views on technology management.

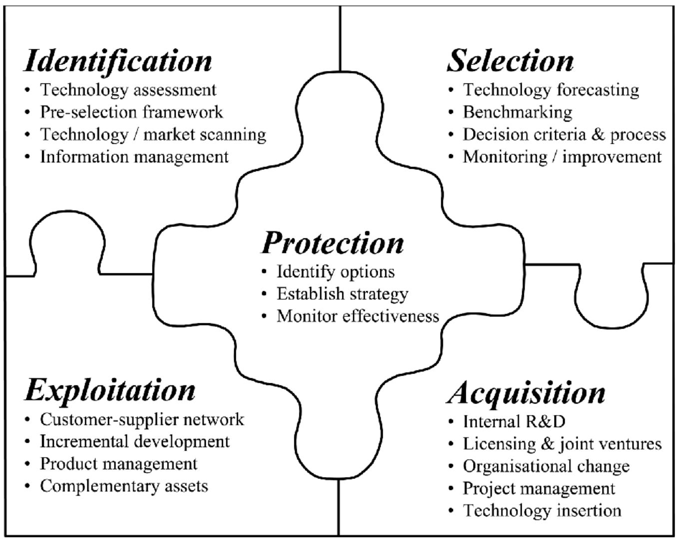
Much of the effort since about 1980 in the area of technology management has been directed towards strategic issues (Drejer, 1997) - i.e. how to integrate technology strategy with marketing and other corporate strategies. For example, Mitchell (1985) has developed a simple matrix linking strategic technology areas (STAs) to business areas. By ranking the value of each STA to each business area, and comparing the strength of each STA with competitors, an effective technology strategy can be developed. This type of approach has been extended by deWet (1996), who has developed an expanded two-dimensional matrix, linking markets, products, processes and technologies, enabling market-focused technology planning. Other examples of approaches to the development of technology strategies include Bitondo and Frohman (1981), Birnbaum (1984), McGee and Thomas (1989), Pavitt (1990), Stacey and Ashton (1990), Matthews (1992) and Abetti (1994). However, no particular approach has been widely accepted.

Effective implementation of a technology strategy requires management of the associated processes at the operational level; ``A strategy is only of value if mechanisms for its implementation and renewal are in place'' (Gregory, 1995). To this end, it is necessary to develop both an accepted framework for understanding technology management issues (see below), and a range of tools and techniques to support the implementation of strategy (for example, De Piante Henriksen, 1997; Chiesa et al., 1996; Tipping et al., 1995).

This paper describes the application of a technology management process assessment procedure, which aims to identify and assess technology management processes in manufacturing organizations. The procedure includes a high-level strategic overview, where the impact of segmented technology areas on business areas is assessed. Specific technology-business areas are then assessed in more detail, to evaluate the effectiveness of operational technology management processes, leading towards the development of practical improvement plans.

2. Technology *management process framework*

Gregory (1995) has proposed that management of technology is comprised of five generic processes (see Figure 1):
(1) *Identification* of technologies which are (or may be) of importance to the business.
(2) *Selection* of technologies that should be supported by the organization.
(3) *Acquisition* and assimilation of selected technologies.
(4) *Exploitation* of technologies to generate profit, or other benefits.
(5) *Protection* of knowledge and expertise embedded in products and manufacturing systems.
This framework is related to other process models that have been proposed for technology management, such as Sumanth and Sumanth (1996) - awareness, acquisition, adaptation, advancement and abandonment - and Jolly (1997) - imagining, incubating, demonstrating, promoting and sustaining. These types of models are often closely related to the innovation and new product development processes; Gregory's framework has the advantage of being quite generic, encompassing all technology management activities in the firm.



Source: Gregory (1995)

Figure 1. Gregory's (1995) technology management process framework, showing examples of activities

Skilbeck and Cruickshank (1997) have extended Gregory's five-process model, linking the framework to business activities within a systems context, and identifying three levels within the organization where technology management processes apply:

(1) *Corporate level* (network view): how to manage technology across a diverse range of businesses.
(2) *Business level* (external view): how to gain competitive advantage through technology.
(3) *Operational level* (internal view): how to optimize internal processes to manage technology effectively.

A technology management assessment procedure (TMAP) has been developed which is based on this model. This paper describes the application of the TMAP procedure in a manufacturing organization.

3. Research *framework*

The development of the technology management process assessment procedure has been undertaken in the context of an ``action research'' framework, as set out by Maslen and Lewis (1994); see also Platts (1993). Action research provides a methodology whereby business systems can be investigated by a process of active intervention (i.e. collaborative participation).

There are two stages associated with action research in this context: development and testing (see Figure 2). During the development stage the procedure is expected to change, incorporating improvements based on experience during its application. During the testing stage the procedure should not change significantly. A prime objective during the testing phase is to develop the contingent framework within which the procedure is applicable (i.e. a classification of organizations within which the procedure has been applied and tested), and for this reason a wide variety of organization types are selected for testing.

A primary aim of the research described in this paper is to develop a practical approach to support communication, decision-making processes and action in companies, which requires close collaboration with industry, working on ``live'' problems. An advantage of an action research approach over more traditional business science research methodologies (e.g. surveys, interviews, case studies, statistical analyses, etc.) is that it encourages a high level of access to organizations, owing to the practical and useful nature of the outputs to the business.

There are dual objectives within each engagement with industry: to contribute to the particular area of company interest, and to extract generic learning that can be captured in the form of a guide and applied to other companies facing broadly similar challenges. The technology management process assessment procedure comprises a series of facilitated workshops, based on a detailed workbook containing procedures and guidelines. The action research approach is essential if such guidance is to be relevant, robust and well tested. However, the approach is fairly challenging from a methodological point of view, as it is not possible in general to establish a ``control'', or to conduct a large number of cases. Each application of the procedure is assessed by means of a questionnaire to workshop participants, relating to the following performance measures:

- *Usefulness*: how well did the procedure address the company objectives?
- *Functionality*: were the generic aims of the technology management assessment procedure achieved?
- *Usability*: how easy would the procedure be to apply independently within the company?

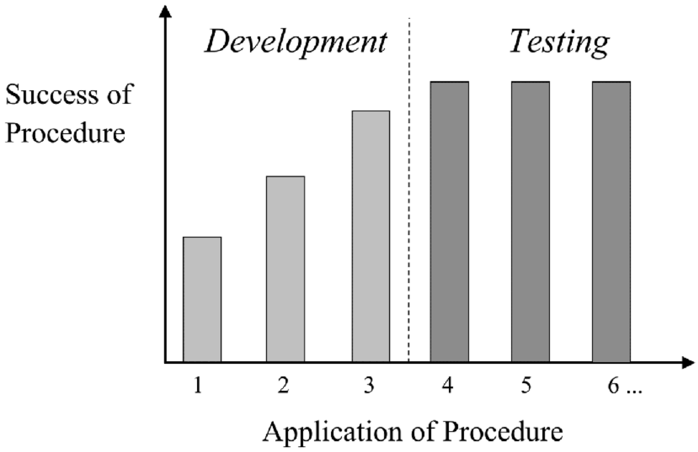


Figure 2. Development and testing stages for procedural action research

4. Technology *management process assessment*

A technology management assessment procedure has been developed which is based on the five-process model of Gregory (1995). The method provides a structured procedure for a top-down investigation into technology management practices in a business unit. The assessment procedure is comprised of three workshop-based stages (see Figure 3):

(1) *Strategic overview*, where the business unit is segmented in terms of business and technology areas. The impact of each technology area on each business area is assessed in terms of value, effort and risk. The strategic overview is similar to methods developed by Mitchell (1985) and de Wet (1996), enabling appropriate technical and business areas to be identified for further assessment.

(2) *Process overview*, where recent, current and future activities are charted for selected technology-business segments. These activities are characterized in terms of the Gregory five-process framework, and assessed in terms of the effectiveness of inputs, process and outputs. Identification of strengths and potential weaknesses enables specific process areas to be identified for more detailed analysis.

(3) *Process investigation*, where specific process areas are mapped in detail, in order to identify areas of good practice, together with barriers and problems, and areas for possible improvement.

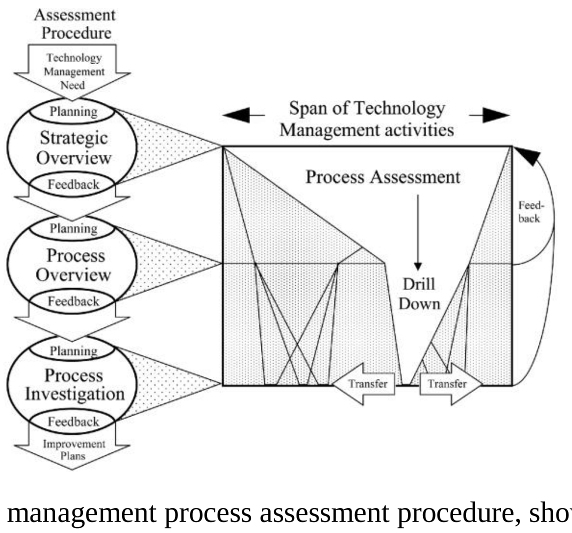


Figure 3. Technology management process assessment procedure, showing top-down approach

Figure 3 shows how the strategic and process overview stages can each result in several areas for assessment in more detail. Thus, many assessment routes are possible, as specific technology management processes are examined. For this reason, careful planning is required at each stage to select appropriate areas for further assessment. Feedback sessions after each workshop link operational and strategic views, and enable the transfer of appropriate results to other technology and business areas.

The technology management process assessment methodology was developed over a period of two years, as described by Paterson et al. (1997). The procedure was then tested within a range of organizations in different industry sectors over a period of one year.

5. Case study

Company background

This section describes the first full (pilot) application of the technology management process assessment procedure. The study was undertaken within the product development group of a company that manufactures electrical wiring devices, circuit protection and cable management systems for domestic, commercial and industrial use. The company is a high volume manufacturer, producing approximately 50,000 different component parts. The annual production volume of mouldings is around 85 million parts and product unit volume is in excess of 100 million.

Strategic overview

The main element of the strategic overview stage of the technology management assessment was a three-hour facilitated workshop. Participants included senior managers responsible for product development, supply processes, marketing, quality, and technology areas.

Segmentation.

The first step was to segment the business in terms of both business and technology areas. This was achieved by brain-storming and discussion. The following business segments were agreed:

- wiring devices;
- cable management; and
- circuit protection.

Technology areas were:

- product design;
- plastic conversion;
- assembly;
- finishing;
- metal forming;
- materials specification; and
- bus systems.

The segmentation process generated healthy dialogue between the different functions within the business, creating an interface between corporate strategy and technology management (deWet, 1996).

Impact analysis.

The impact of each technology area on each business area was assessed in terms of value, effort and risk. The meaning of these parameters needed to be defined in the context of the company:

- *Value*: what level of competitive advantage does each technology area provide for each business area? (i.e. ``how good do you have to be?'').
- *Effort*: what level of effort is being directed at each technology area for the benefit of each business area? (i.e. ``how hard are you trying?'').
- *Risk*: what level of risk is associated with realising the competitive advantage of each technology area for each business area? (i.e. ``how hard is it to be good?'').

Value, effort and risk were assessed for each cell of the business-technology segmentation grid, and ranked as high (H), medium (M), low (L) or not significant (-), as shown in Table I.

In general, there is expected to be some correlation between value, effort and risk. Thus, cells where there was a significant mismatch between value, effort and risk were highlighted for discussion. The ranking activity generated considerable debate, and efforts were made to capture useful comments.

An alternative view is given in Table II, where the number of instances of cells ranked high, medium, low or insignificant are shown for effort-risk, value risk and value-effort combinations. The diagonal cells in these grids represent a good balance between effort and risk, value and risk, and value and effort. It can be seen that the level of value attributed to each cell is generally well balanced by the level of risk, while effort never exceeds the level of value or risk

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Table I. Business/technology segmentation showing impact analysis

Technology	Wiring devices Value-Effort-Risk	Business Cable management Value-Effort-Risk	Circuit protection Value-Effort-Risk
Product design	HHM	HMM*	HLM*
Plastic conversion	HMH	HLM	M – L*
Assembly	HMH	L-L	H-L*
Finishing	M-M*	L-L	L-L
Metal forming	MLL	L- –	M-L
Materials specification	MLM	HLH*	M-L*
Bus systems	L-H	L-H	L-H*

Note: *significant value-effort-risk mismatch

Table II. Relationship between effort and risk, value and risk, value and effort

Effort versus risk					
Effort			Risk		
Total	1	7	5	8	21
H	*0*	*0*	*0*	*1*	1
M	*0*	*0*	*1*	*2*	3
L	*0*	*1*	*3*	*2*	6
–	*1*	*6*	*1*	*3*	11
Value versus risk					
Effort			Risk		
Total	1	7	5	8	21
H	*0*	*1*	*3*	*5*	9
M	*0*	*3*	*2*	*0*	5
L	*1*	*3*	*0*	*3*	7
–	*0*	*0*	*0*	*0*	0
Value versus effort					
Effort			Effort		
Total	11	6	3	1	21
H	*1*	*4*	*3*	*1*	9
M	*3*	*2*	*0*	*0*	5
L	*7*	*0*	*0*	*0*	7
–	*0*	*0*	*0*	*0*	0

Following discussion of the above results during the strategic overview feedback session, the technology area of finishing was selected for further assessment, owing to the significant level of mismatch identified for the business area of wiring devices (which represents 60 per cent of revenues). Although the high-quality finish of company products was perceived to be a source of competitive advantage, little effort was expended on managing this technology proactively.

Process overview

The main element of the process overview stage of the technology management assessment was a four-hour facilitated workshop. Participants represented business and technology areas associated with finishing.

Key technologies.

The first step was to decompose the finishing technology area into key technologies:

- wet finishing;
- dry finishing;
- marking;
- surface preparation;
- self finishing;
- plating; and
- novel finishes.

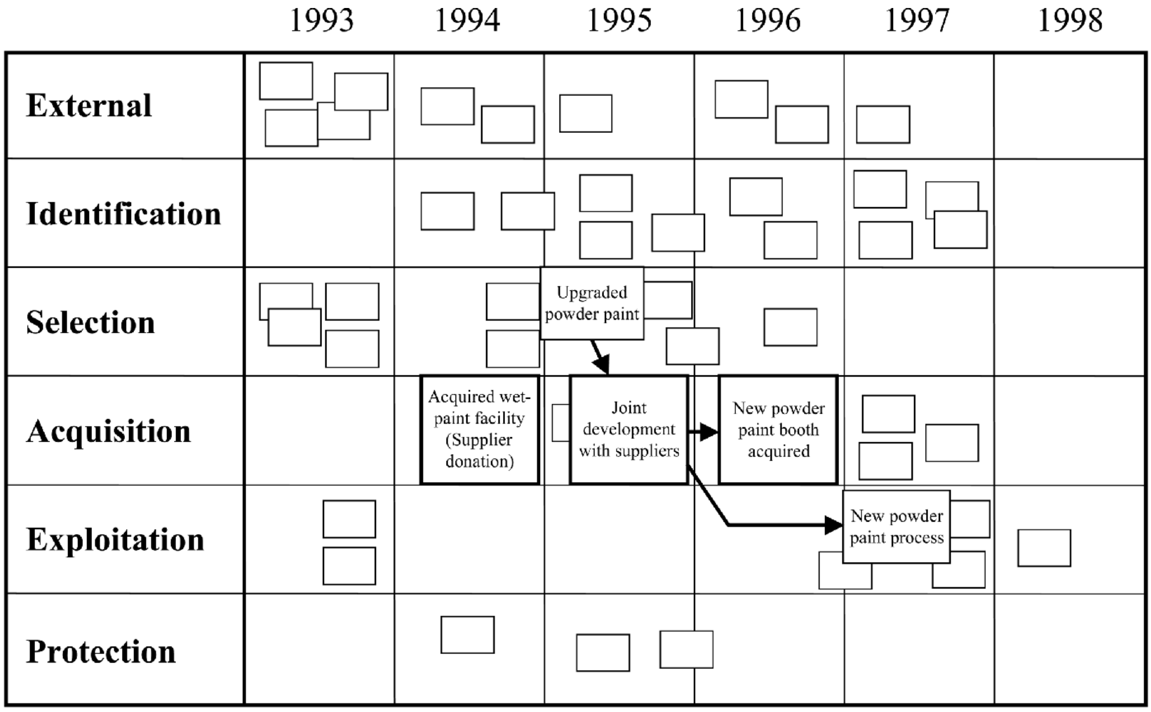
Internal and external dependencies of these key technologies were identified, in terms of the business areas established during the strategic overview.

Activity charting.

In order to assess technology management processes it is helpful to identify specific instances of recent events and activities. This was achieved by a time-based charting exercise, where workshop participants identified significant events and subsequent activities, together with associated links, based on the key finishing technologies. The activities were categorized in terms of the five generic technology management processes:

(1) Identification;
(2) Selection;
(3) Acquisition;
(4) Exploitation; and
(5) Protection, illustrated in Figure 4.

The number of events and activities recorded during the charting exercise was used to estimate the approximate level of activity in each of the five process areas. For finishing technologies, a total of 11, 10, 6, 4 and 3 specific activities were recorded for the process areas of identification, selection, acquisition, exploitation and protection, respectively, with few events or likely activities identified for the future. The higher number of activities associated with technology identification and selection processes reflects the large variety of finishing technologies and processes that are available on the market. The company was at that time undertaking a product strategy initiative which was likely to extend technology planning to the future.



Note: Details are shown for the specific process areas and technologies (wet-paint and dry-powder) selected for detailed process investigation/mapping

Figure 4. Activity charting, showing distribution of events and activities

Process assessment.

The specific activities identified during the charting exercise were used as the basis for assessing the effectiveness of technology management in each of the five process areas. This was achieved by considering the three components of a generic systems model (i.e. inputs, process and outputs). The participants of the workshop were asked to rank the effectiveness of each component with respect to a series of statements, on a scale from1 (strongly disagree) to 5 (strongly agree):

- *Inputs*: ``The requirement for this activity was always clearly defined''.
- *Process*: ``The activity was always well managed''.
- *Outputs*: ``The results for this activity were always exploited''.

Each process area was further divided into sub-categories. For instance, identification, selection and protection processes were separated into reactive and proactive types. Reactive processes were further sub-divided into those which were triggered by production stoppages, and those which resulted from competitor activity or marketing requests. Acquisition and exploitation processes were sub-divided into internal and external types. The results of the process assessment are shown in Figure 5.

The process assessment activity generated considerable debate, and efforts were made to capture useful comments. Following discussion of the above results during the process overview feedback session, the process area of external acquisition was selected for further assessment.

Process investigation

The main element of the process investigation stage of the technology management assessment was a two-hour facilitated workshop. Participants represented business and technology areas with direct experience of two areas identified during the activity charting (see Figure 4): dry-powder and wet-paint technologies. For each of the selected technologies, the acquisition process was mapped in detail, using non-formal methods (see Figures 6 and 7).

The acquisition process for the two selected technologies represented entirely different mechanisms of acquisition. The dry-powder technology was acquired as part of a new product development project, while the wet-paint technology was a corporate acquisition, involving the reclamation of a facility run by a supplier.

The specified processes that were mapped were then compared to a generic process model for technology acquisition, shown in Figure 8. This was achieved by a series of questions considered individually, regarding the effectiveness of each stage of the process, together with group discussion. This enabled the strengths and potential weaknesses of the processes to be determined.

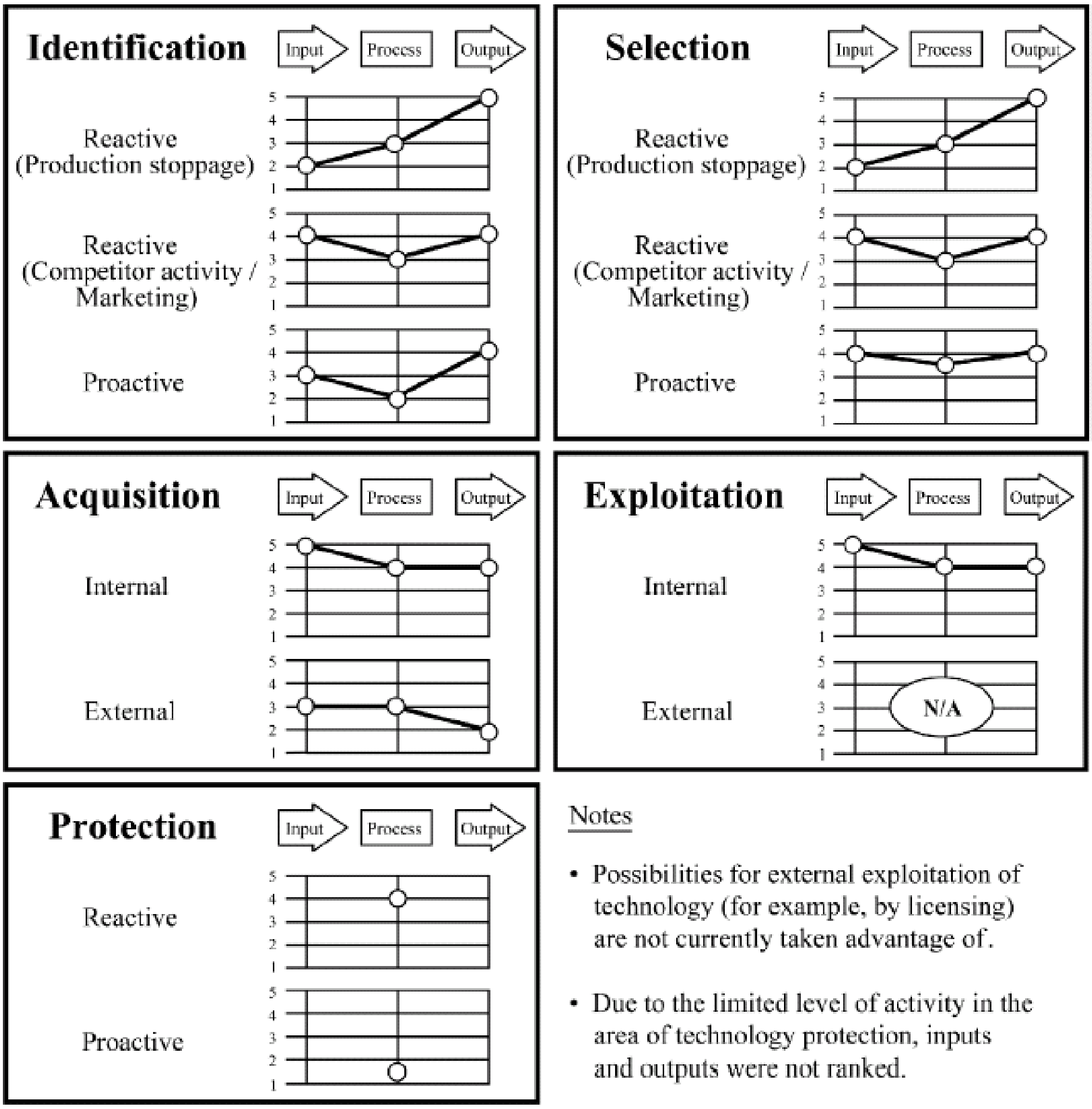


Figure 5. Process overview assessment results

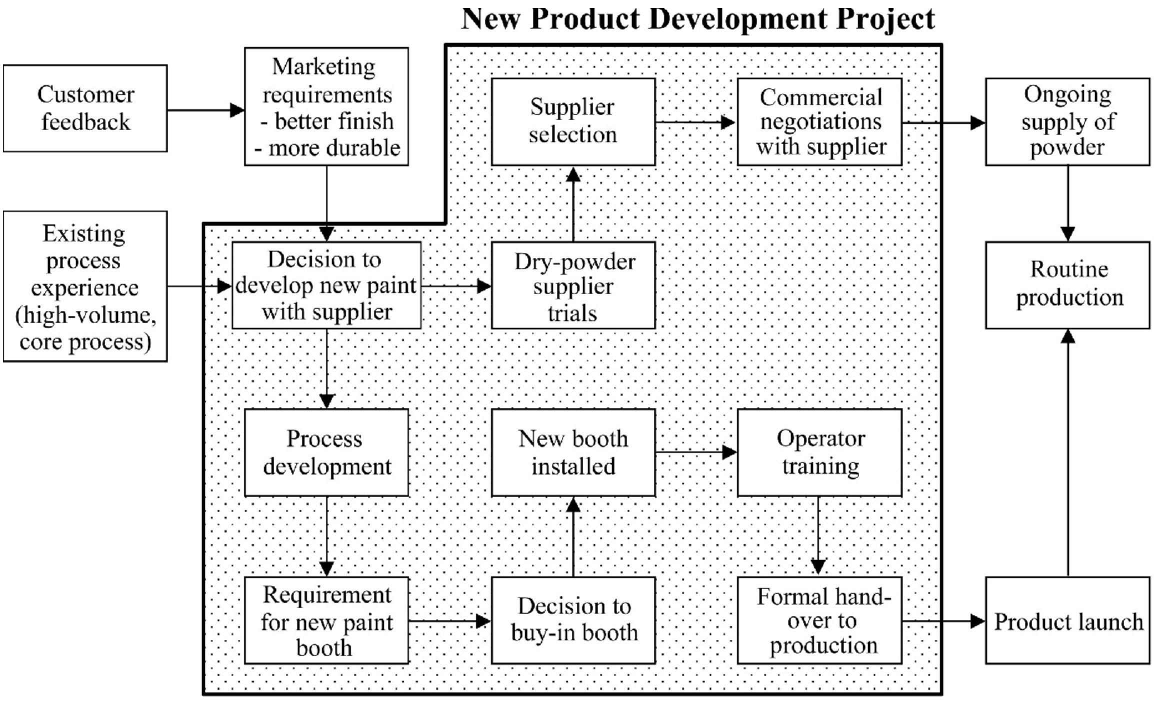


Figure 6. Process map: acquisition of dry-powder technology

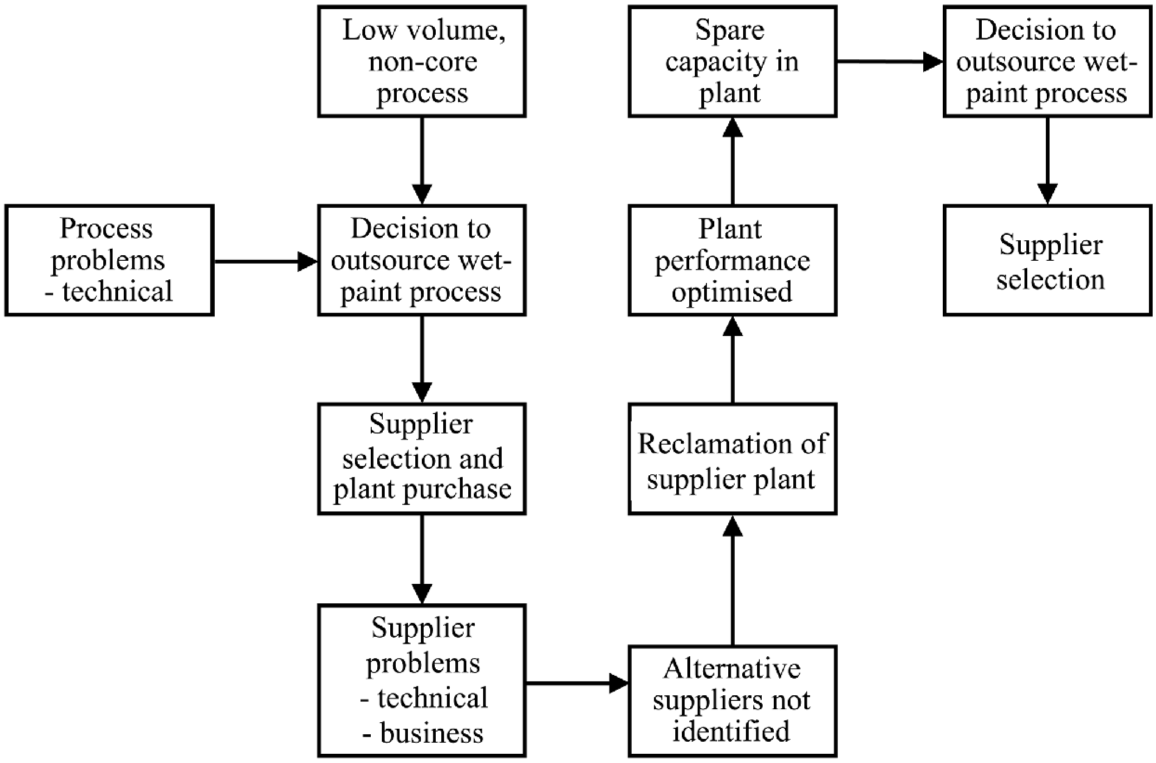


Figure 7. Process map: acquisition of wet-paint technology

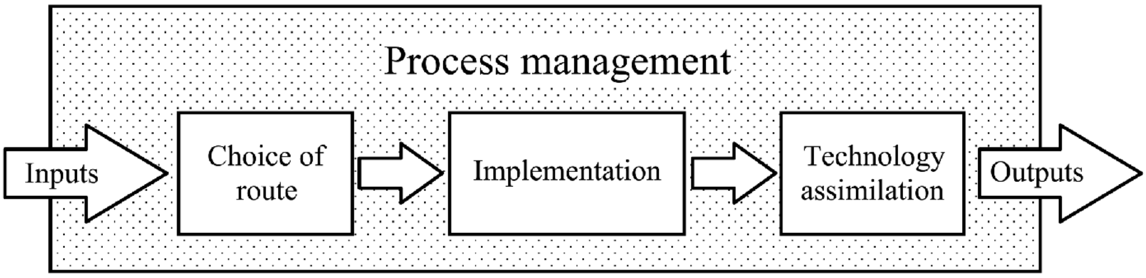


Figure 8. Generic technology acquisition process

The main strength associated with the successful acquisition of the dry-powder technology was the strong project management process for new product development, based on multidisciplinary teamwork, supported by in-house knowledge of the technology. On the other hand, there was a history of cyclic acquisition and outsourcing for the wet-paint process, which has not been managed as a formal project. The low-volume wet-paint process was not considered to be a core technology, although technical difficulties associated with the required high quality finish have made outsourcing difficult. The decision to outsource this technology was largely driven by financial considerations.

6. Discussion and conclusions

Company experience

The feedback from the company during this pilot study was positive at each stage of the technology management process assessment:

- The strategic overview provided a means of assessing the impact of technology on the business.
- The process overview and investigation stages identified technology management activities, and areas of strength and potential weakness, in terms of the generic processes involved in technology management and for the specific processes that were mapped.
- The workshop format resulted in enhanced awareness and communication of technology management issues.

The timing of the assessment was an important factor contributing to the success of the assessment procedure within the company, which was at that time undertaking an extensive product strategy initiative, including product road mapping. The culture in the company was conducive to this type of workshop-based procedure, which also requires the support of an internal assessment ``champion''.

The company planned to undertake further technology management process assessments internally. Other areas of interest identified during the assessment include plastic conversion technologies, together with identification, selection and protection of finishing technologies.

Technology management process model

The generic five-process model for technology management (i.e. identification, selection, acquisition, exploitation and protection) was accepted to be useful by the company. However, few companies appear to actually manage technology explicitly in terms of this framework. The five technology management processes, which generally comprise many different specific activity types in different parts and levels within the organization, are typically embedded in other business processes (such as new product development projects for acquisition). Thus, in order to bridge the gap between the existing business processes and the conceptual framework provided by the five-process model, it is necessary to identify the technology management activities by means of devices such as the activity charting exercise.

The challenge for managers wishing to integrate technology into the business more effectively is to ensure that technology management process issues are embedded within other relevant business processes and activities. For instance, technology management should be an issue that is considered within business strategy, supply chain management and new product development processes. The key benefit of Gregory's technology management process model is that it provides a conceptual framework that can be used to bring the fragmented activities that constitute technology management in the firm together, allowing overall assessment and management of this important dimension of the business. The framework is simple to understand and communicate, but its application can be challenging due to these considerations.

Modifications to assessment procedure

Based on the experience of this application, some minor modifications to the process assessment were made. These modifications were aimed at improving the usability of the procedure, and mainly concerned guidance for the facilitator. Specific areas that required improvement are listed below:

- This application of the strategic overview stage of the assessment procedure considered the impact of current technologies on the current business areas. It would be desirable to also include a future perspective, to aid strategic planning.
- The assessment of the technology management activities during the activity charting exercise was based on all activities associated with each process. It would be helpful to categorize the important sub processes prior to assessment, as each sub-process type can have completely different characteristics. Thus, for the case study described above, the two types of processes identified during the process investigation stage should have been assessed separately.
- Additional guidance regarding the semantic content of the assessment procedure was required for the facilitator at each stage. The meaning of words such as value, effort and risk, together with qualitative measures of process effectiveness, generated considerable debate within the workshops. This dialogue was useful, but more accurate definitions of terms would be helpful.
- All stages of the assessment procedure required qualitative evaluation of either the impact of technologies on the business, or the effectiveness of specific processes. Some rationalization of the procedures for numerical ranking of impact and effectiveness was required, together with additional guidance for the facilitator.

Owing to time constraints it was not possible to fully explore all the issues raised during the assessment procedure. The various stages of the procedure suggest off-line activities that would be useful for the manager concerned with technology management. For instance, the segmentation of the business during the strategic overview stage could be extended to include a more complete classification of technology areas.

Research framework

The pilot study described in this paper was the first full test of the technology management process assessment methodology (see Figure 2). It highlighted the need for some additional minor adjustments to the assessment and provided a firm base for the testing and validation phase that was to follow as part of the action research methodology adopted. The case study raised the following key issues:

- In order to demonstrate causality it is necessary to show that the procedure works in a range of different companies with different facilitators (see below). Evidence that the procedure itself caused the observed effects identified during the assessment process is helpful, although such evidence is typically anecdotal.
- The procedure was shown to be effective in the context of the case study company, although the case revealed some improvements that were

required to improve the usability of the procedure.
- It was anticipated that the procedure is generalisable, owing to the generic nature of the five-process technology management model. The range of cases covered during the development and testing stages of the procedure supports this claim (see below). However, to ensure the general applicability of the approach requires an emphasis on the effective mapping of the assessment procedure onto each business unit and situation being considered, which requires comprehensive facilitator guidance, combined with the support of an internal champion. This is of particular importance when the top-down nature of the procedure is considered, where many assessment routes are possible (see Figure 3).

Industrial application

The assessment procedure (Phaal *et al*., 1998; Probert *et al*., 2000) has been applied 13 times in a total of 11 organizations during the development and testing phases (one example of which is described in this paper). The development phase was used to prototype procedure components and the testing phase to validate the integrated procedure. Industry sectors included: aerospace, automotive, electronic, electrical, marine, construction and pharmaceutical, including high-, medium- and low-technology organizations, with staff numbers ranging from about 20 to more than 5,000. In addition, the procedure has been applied within an independent academic organization (i.e. a non-manufacturing service-based environment).

The procedure has subsequently been successfully applied on an independent basis, and has been recently published (Farrukh *et al*., 2000). The guide is designed for use by managers in industry and includes much of the tacit knowledge generated during its development and application in the form of process and facilitation guidance.

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