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Technology Management for Hidden Advantages

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Abstract — *This study addresses the fragmentation in the technology management field by identifying and organizing the routines used by managers of technology. In a multi-method, iterative qualitative study done jointly between academics and technology managers from a number of large industrial firms, 27 technology Management routines was identified. These 27 routines were organized into a framework consisting of four categories: producing scientific and technological knowledge, transforming knowledge into working artifacts, linking artifacts with user requirements, and providing organizational support. This framework provides an organizing scheme to make sense of technology management Routines. In addition, because managers of technology actively participated in developing the routines, the study contributes by identifying routines practitioners regard as particularly important. Both research and practical implications are derived from the framework.*

Keywords- *process; routine; technology management framework.*

I. INTRODUCTION

Technology and technology development are critical to the health and survival of modern organizations and provide firms with an enormous economic multiplier effect (Roussel et al., 1991). The management of technology requires the integration of multiple activities from different parts of the organization, a task with which many corporations struggle, especially in the face of increasingly high-velocity environments. Research and development (R&D) groups, for example, often have strained or problematic relationships with other parts of the organization: Perceptions that business units (and their customers) do not want enough of the technologies that R&D develops are as likely to occur as are perceptions that R&D does not develop enough of the technologies that business units do want. In addition, complaints about the expense and time needed for technology transfer and the poor communication between business units and R&D are typical.

In dealing with these problems, however, practitioners feel that the literature on the management of technology is too sparse and fragmented and does not adequately address their concerns, issues, and problems (Levin et al., 1997; National Center for Manufacturing Sciences, 1996). For example, there is a general sense in the literature itself that the many detailed mathematical models of project selection are rarely, if ever, practical (Baker and Pound, 1964; Carbno, 1999; Jones and Twiss, 1978). Moreover, 'the literature on the management of technology is a fragmented one, and one largely lacking in an overarching framework.' (Levin et al., 1997). In a joint study between academics at two US research universities and a group of a half-dozen major US companies (under the auspices of the National Center for Manufacturing Sciences), a literature review1 confirmed the impression of these practitioners and the findings of Shenhar and Gaynor (1996) that the literature in this area is fragmented and incomplete. To begin integrating these various aspects of technology management into a useful and systematic framework, this joint academic–practitioner partnership began a study to identify the routines that the technology managers of large organizations actually use.

The current paper describes the results of this study and provides a framework of technology management routines that is analytically rigorous for scholars while practical and helpful for practitioners. From a theoretical perspective, the study is situated within a resource-based view of the firm (Collis,1994; Grant, 1996; Levitt and March, 1988), where the firm's ability to manage the creation and application of technology is regarded as central to a firm's long-term success. By foregrounding the routines through which technology is managed, the potential and importance of organizational learning is also recognized. Of course a major difficulty in trying to increase organizational learning in the technology management domain is the sheer complexity of this domain (Cohen and Levinthal, 1990). By methodically and comprehensively identifying and organizing the organizational routines in the technology management domain, this paper develops a new way to see the technology management 'landscape'. This work thus complements more traditional approaches – such as those focusing on organizational types, characteristics, and structures (Tidd et al., 2005) – by providing researchers and managers with a new lens of analysis in the technology management domain.

II. ROUTINES IN TECHNOLOGY MANAGEMENT

The current study focuses on routines (i.e. on what practitioners often call processes) in the technology management domain of large corporations. Organizational routines are defined as 'the regular and predictable behavioral patterns within firms that are coping with a world of complexity and continuous change' (Pavitt, 2002, p.117), or stated

differently, 'as a coordinated, repetitive set of organizational activities' (Miner, 1991, p.773). Traditionally, in the study of technology management, either the individual, the group, or the organization is used as the unit of analysis (Roberts et al., 1978). What this paper proposes is that the routine also be used as a unit of analysis. By focusing on routines, the emphasis is not so much on the actors per se but
on their activities. Routines are often seen as the building blocks of organizational learning and knowledge management (Levitt and March, 1988; Miner, 1990), and this study looks at organizational routines and interprets them as firm capabilities that evolved in response to technology management requirements.
There is, however, a controversy over how it is that routines can be repeated and predictable on the one hand, yet on the other hand still facilitate change and innovation. This inherent tension was recently addressed by Zollo and Winter (2002), who argue that routines can be designed specifically to enhance innovation and thereby form the basis for dynamic capabilities. This argument is consistent with earlier work (Teece et al., 1997) that distinguished dynamic capabilities from more static resources as a source of competitive advantage, with routines forming the basis for these dynamic capabilities. These theoretical approaches to innovation-related routines, however, have rarely been examined empirically. One exception has been an empirical study of the routines involved in technology brokering (Hargadon and Sutton, 1997). In the current paper, we focus more broadly on identifying and describing all the major technology management routines used by large firms. From a technology management perspective, the result is a framework that:

- better connects strategic (macro) and project (micro) levels of analysis (Burgelman, 1983)
- better understands the terminology, jargon, and thought patterns (i.e. the 'cognitiv ecategories') that people use to describe technology management and how work gets done.
- better connects to the increasingly important resource-based view that specialized knowledge and routines are one of the few, if not only, sources of sustainable strategic advantage (Collis, 1994; Grant, 1996; Levitt and March, 1988)
- better translates rigorous research into findings useful to practitioners, a goal endorsed by leading academic scholars (Hambrick, 1994; Mowday, 1997).

Because the routines in this study were jointly formulated by managers of technology, their perspectives and preoccupations have shaped how the routines are defined. Some routines are presented in general terms ('provide post-project support'), while others are more thoroughly delineated (e.g. five different kinds of strategy-formulation routines). It is certainly possible that other actors in the creation and dissemination of new technology – for example, scientists or new product development teams – might identify, or at least emphasize, different routines. However, we argue that this potential variance is meaningful. Since the participants – who are managers of technology, not technologists – described the routines that they were more concerned about in great detail, the framework of routines in this paper does not provide a neutral rendering of all the technology management routines that can be – or need to be – found in firms. Rather, it provides a map of those routines that matter most from the perspective of the people charged with managing their firm's technological resources.
Our contribution, then, is to clarify and identify which are the routines that facilitate technology management and innovation in firms; i.e. routines that can be the basis for dynamic capabilities (Teece et al., 1997; Zollo and Winter, 2002). In addition, we categories these routines in a way that is consistent with the literature on innovation, especially incremental and architectural innovation (Tushman and Smith, 2002). Later, in Section 5, we consider the limits and consequences that our focus on technology managers has for how firms deal with discontinuous innovation

III. METHODOLOGY

The origin of this study occurred when a group of manufacturing-oriented companies approached a major US research university to ask for help in better understanding and dealing with the management of technology, as they had found the technology management literature fragmented and unhelpful. The practitioner group consisted of representatives from six large manufacturing-oriented firms (e.g. in industrial products, consumer goods), mostly senior technology or engineering managers whose jobs focused primarily on business-related issues. The academics consisted of several professors and PhD students, in both the business school and engineering school at two US research universities. The joint team was charged with documenting the state of the literature in this field and with developing a new framework that would encompass much of the academic research up to that point and also be firmly rooted in practitioner concerns. Three sources of data – a literature review, field visits, and working sessions with technology managers from participating companies – were used iteratively to develop this framework (Eisenhardt, 1989; Glaser and Strauss, 1967). The process was documented in the minutes of meetings, in e-mail exchanges among participants, and in participants' presentations and critiques of draft frameworks.

The academic team started developing a literature review in response to the practitioner request, beginning with Adler's (1989) extensive review of the technology management literature and working backwards and forwards in time from there. The team worked backwards in time by using many of Adler's categories and identifications of the key existing research. The team worked forwards in time by noting which journals were most cited in Adler's comprehensive bibliography, and then combing through those journals2 in addition to several organizational journals3 and miscellaneous other relevant articles, books and recent PhD dissertations. In all, the academic team identified 441 texts (mostly articles). All of this literature was categorized and re-categorized, as the overall framework emerged.

The literature review was distributed among practitioners for comments, and was also used to identify core issues for the field visits and working sessions. The field visits consisted of interviews with two dozen managers and engineers at various hierarchical levels in the corporate staff functions, business units, and R&D labs of two different large companies participating in the project. The interviews were largely open-ended, but centered on the routines and issues facing the interviewees in their daily work. The team also examined and analyzed company documents, specifically organization charts and attempts to routinize technology management; e.g. flowcharts and forms required for different stages.

Thirdly, in parallel with the literature review and the fieldwork, was a series of joint working sessions with practitioners over a period of several months. During these sessions – conducted mostly in person but sometimes by conference call – the academic/practitioner team discussed what, in the experiences of practitioners, were the main technology management routines, using some of the literature and fieldwork findings as an initial baseline. An important advantage to using a Delphi-type technique, rather than just literature and fieldwork, is that it allows cross-company interaction among participants. This ensures that routines are actually widely enacted, although it does result in a loss of firm-specific detail due to competitive and proprietary concerns.

The approach to data gathering in this research represents somewhat of a departure from most qualitative research, which tends to involve the researcher generalizing from the activities of practitioners. In this case, practitioners were themselves engaging in the literature, analyzing practices, generalizing, and generating conclusions. Academics acted mainly as facilitators, identifying and sharing literature, suggesting terminology if a suitable term existed, and documenting the process. In our view, it has been of great benefit to have key participants from participating firms provide critiques and refinements to the routines-based framework as it emerged.

Throughout the data gathering process, descriptions of technology management routines were disseminated among all project participants for discussion. Then, practitioners and academics alike considered questions such as: does this routine really operate as described? What other routines does it link to? What routines are missing from this list? The team looked for cross-firm commonalities in the technology management domain, focusing on generic routines and their interrelationships. Some firms used different names for the same routine, and depending on the firm, routines were sometimes formalized, and sometimes not. The emphasis, however, was on the existence of a repeated set of related activities in this domain, regardless of degree of formalization or name. A routine was only included if all participants reached consensus that it represented a valid unit of related activities; this necessitated extensive dialogue and debate. After several iterations of literature review, field interviews, and joint analysis meetings, an overall framework of 27 generic technology management routines emerged.

In parallel with the identification of routines, there was a process of categorization. A division derived from Adler (1989) was used as a starting point and refined based on dominant themes in the literature as well as a 'reality check' by practitioners. At the same time, and in accordance with the process of grounded theory building (Strauss and Corbin, 1998), clusters of routines emerged from the working sessions. An iterative process was followed to link these clusters into an overarching framework: the academic/practitioner team discussed proposed schemes of categorization, and adjusted their categorizations. This process proved to be very difficult, which, given that the study was spurred by a concern with the fragmentation in the field, is hardly surprising.

The difficulties encountered by participants reflect that there is indeed not yet a consensus framework for how technology management routines interrelate. Participants found it fairly easy to agree on the specific routines involved, and could also identify sub-groups of routines. However, they struggled to generate an overarching framework. In each case, participants encountered difficulty when attempting to apply existing schemas of organization in businesses to the management of technology. They used the corporate versus business unit versus R&D distinction, experimented with project management and value chain principles, and settled on a (less than satisfying) strategic-, portfolio-, and product-level categorization. Feeling that a more appropriate schema would be based on similarities in terms of the routines themselves, rather than where those routines are situated, the researchers revisited participant inputs and the literature, and revised the organizing scheme. Thus the ultimate categorization of the 27 routines represents the input of academics, but practitioners have generated the definition and content of each routine.

To limit repetition, the discussion of the organizing scheme and the routines that constitute each dimension in the scheme will be discussed together.

VI. RESULTS

The development of new technology is a non-linear iterative process (Angle and Van deVen, 1989). Successful innovative companies manage technology so that they are able to combine their knowledge of the requirements of customers – who are we servicing and what do they want? – with the company's (expanding) technological capabilities (Dougherty et al., 2000). Any framework for technology management routines must therefore accommodate both the expansion of technological capability and the determination of customer requirements. While Tushman and Smith (2002) do discuss both technology and market aspects of innovation, their framework concentrates on *types* of innovation (incremental, architectural, discontinuous) but not the actual activities of innovation, as captured by a focus on routines. Similarly, Tidd et al. (2005) focus their framework on organizational design characteristics of innovation (e.g. degree of centralization, creative climate), but not the actual routines used in the technology management domain. Thus, in choosing a framework that would be consistent with these other perspectives on innovation – yet still describe the more

detailed world of innovation-related routines – we were drawn to the work of Pavitt (2002). Pavitt (2002) has suggested dividing innovation into three partially overlapping dimensions:

- producing scientific and technological knowledge
- transforming knowledge into working artefacts, reflecting that technological or scientific possibility does not necessarily imply practical feasibility
- matching artefacts with user requirements, whether internal (e.g. in the case of process innovation) or external (where the goal is new product innovation).

Since Pavitt's framework suggests the importance of both the user and the knowledge base, it presents a useful framework for categorizing technology management routines.
However, we identified one additional category organizational support routines – that cuts across the three other categories. In fact, to the extent that these four broad categories in themselves constitute repeated, coordinated sets of activities, they can be seen as 'master' routines.

IV. IMPLICATIONS

The 27 routines identified in this study provide a high-level view of what the generalist manager of technology needs to oversee. The routines are presented in a framework that cuts across functional boundaries (as technology management often requires) yet is intuitive enough to facilitate sense making by managers of technology. The four categories of the framework themselves represent 'master' routines, providing a clear but fluid organizing schema for the fragmented field of technology management. In addition, the framework emphasizes the non-linear nature of technology management. So a technology management sequence can be prompted by a new technological discovery a newly defined user need or attempts to combine known technologies with known user needs.

Although there are a number of articles that describe the functioning of specific technology management routines (e.g. Kappel, 2001), there has been as yet no attempt to describe comprehensively the routines found in this domain in large organizations. This article presents a cognitive map for identifying and making sense of these technology management routines. We list, describe, and organize the routines that technology managers of large firms identify as important in the management of technology, all within a comprehensive yet intuitive framework. This research thus provides a practical 'checklist' of the routines that technology managers agree must take place in order to manage technology effectively in a large firm, and provides practitioners with a point of comparison against which to measure their own routines.

To the extent that the framework can serve as a counterpoint to the fragmentation of the current literature, this study can benefit practitioners (including students wishing to become practitioners) and academics alike. For academics, this study provides a descriptive baseline of the technology management routines used in large corporations. This consensus map, then, can be used by academics to compare theories of innovation management, including future proposals of optimal engineering-management configurations, with actual work practices. This would allow academics to identify possible blind spots – both of practitioners and of researchers and address them in future research.

Along these lines, we note that technology managers appear to be more focused on routines related to incremental and even architectural innovation (Tushman and Smith, 2002), but less so on managing discontinuous innovation. An open question, then, would be: is discontinuous innovation ever routinized, or is it – either in practice or by definition – a 'one-off' and rare phenomenon?
One possibility is that the discontinuity of an innovation is a boundary condition for the framework of technology management routines presented here, which, in this view, would not apply to disruptive technologies. If this is in fact the case, then this would help explain why so many firms suffer from 'routine rigidity' (Gilbert, 2005), i.e. the finding that firms often fail to change organizational processes when circumstances change (Teece et al., 1997; Tushman and Anderson, 1986). That is, in contrast to the view that firms are *unwilling* to embrace discontinuous innovation because they are 'held hostage to their successful pasts' (Tushman and Smith, 2002, p.395), it could also be the case that firms are *unable* to introduce discontinuous innovation because they so rarely confront it and therefore have no routines for it. On the other hand, one could argue that technology management routines do in fact apply to discontinuous innovation. For instance, as noted in Section 4, several of the routines – e.g. R&D portfolio management (routine D), technology needs assessment (routine S), new business unit development (routine X) – do address the issue of radical innovation, according to the technology managers in our study. While discontinuous innovation is relatively rare (Rosenberg, 1982), it would nonetheless be helpful if future research could determine the extent to which this type of innovation is – or can be – routinized.

VI. CONCLUSION

During this study's data gathering sessions, participating technology managers commented how helpful it was for them to be able to compare and contrast their technology management routines with those of other organizations. The academic

field of technology management, struggling to come to terms with the increasing pace and extent of technological progress, can also benefit from hearing how practitioners make sense of their daily responsibilities. Practitioners in technology management are engaged in problem solving in their areas of expertise on an ongoing basis and therefore have the potential to offer valuable insights to scholars. This study complements existing research on technology management, where the insights of practitioners are often left unexamined, by foregrounding the voices of practitioners. In particular, this study offers a map of the technology management routines that technology managers regard as important, organized in a way that is consistent with the non-linearity of innovation. In so doing, it provides a benchmark of technology managers' practices that can inform future innovation management studies.

VII. REFERENCES

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