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IDENTIFYING TECHNICAL RISK SOURCES IN SMALL TECHNOLOGY-BASED FIRMS: A QUALITATIVE INVESTIGATION

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ABSTRACT

This paper is a result of the author's experience as an advisor to technology-based firms and reports on a portion of an on-going stream of research activities directed toward determining whether these firms face unique risk sources. Small technology-based firms were interviewed to determine the various sources of risk they encounter. The findings indicate that a variety of risk sources associated with technology are faced by these firms. In addition, the research indicated that a framework previously developed is capable of capturing risks across a range of industries without losing its applicability to individual firms. This preliminary report holds promise for the development of assessment tools that will assist entrepreneurs in identifying and managing these risks.

INTRODUCTION

The researcher's interest in the role of technology-based risks in small technology-based firms came about as a result of providing counseling to small firms over a 5-year period. It became apparent that there were sources of risk faced by these firms that more traditional firms did not face. At the same time the researcher realized that there are significant differences in the way small firms and large firms operate. Small firms generally do not have the same level of access to resources that large firms have, nor do they generally have the same level of in-house expertise. Over a period of about eighteen months the researcher became increasingly aware of the number of these risk sources that appeared to exist. A listing of these that the researcher pored over and "played with" for several months led to the idea for this project.

All new businesses must deal with issues related to risk. One of the main reasons entrepreneurs prepare business plans is to demonstrate to themselves and other interested parties that risk issues have been identified and dealt with in a reasonable manner. Traditionally, however, business plans have tended to focus on marketing, financial and management risk issues. In recent years there has been a burgeoning of new, small and medium-sized firms in the technology sector, including fields as diverse as bio-technology, telecommunications, information technology and software development, among others (Roberts, 1991). In the author's experience, many of the new product developments in these industries originate in smaller firms and small firms are often the users of new technological processes developed by others. In this context it becomes relevant to ask whether these technology-driven firms are called upon to deal with risks that more traditional firms are not. This is a relatively unexplored area academically. Although there is a body of literature associated with the technology-based risks that larger firms face, researchers have yet to address whether the risks faced by small firms are similar, or whether small firm entrepreneurs attach the same relative importance to them.

If technology-based firms do indeed face a unique or distinctive set of risks, one might also question the effectiveness of existing methods for identifying, assessing and managing these risks. Corporate strategy has been criticized for focusing on financial and marketing factors while neglecting technology as a key resource to be planned (Husain and Sushil, 1997). Similarly, business plans provide valuable guidance in leading the entrepreneur through a rather thorough and systematic consideration of both market and financial risk. The widespread acceptance of a relatively standardized business planning approach, however, raises the question of the degree to which the planning needs of technology-based businesses are being met. If weaknesses do exist, communication of risks may be poor, incomplete and inconsistent, resulting in an lack of understanding of the risks that threaten the project and an inability to identify early warning signals and implement mitigating strategies (Branscomb et al. 2000; Tah and Carr, 2001). Such symptoms, it can be surmised, might themselves also be interpreted as early warning signals by potential supporters, investors and other stakeholders.

The study presented here is one phase of a larger project to develop a comprehensive framework for the identification, assessment and management of risks stemming from the technology-based nature of an enterprise. The spirit and nature of the investigation are still very much exploratory. The current study builds on the results of an earlier study (Hanlon, King and Rogers, 2002) which sought to address these questions based on a review of the literature. The outcome of the literature review provided a coarse and tentative framework for organizing and understanding the scope and nature of the risks distinctive to technology-based firms. In the follow-up study reported here, the same broad questions are addressed using in-depth interviews with a sample of 10 technology-based firms.

RESEARCH QUESTION

The question to be answered by this research project is, "What do entrepreneurs in small technology-driven firms see as the most important technology-based risks they must deal with during the process of bringing new products from the conceptual through to the commercialization stages?"

LITERATURE REVIEW

Although based on the author's experience there is no dedicated body of research that seeks to address the risks facing technology-based enterprises in a comprehensive manner, there are an extensive number of works aimed at understanding and assessing technology-related risks. These tend to be fairly narrow in scope because they reflect the concerns of a particular research discipline or the concern of a particular industry. In particular, the presence of a wide range of research domains including strategic management, marketing, operations management, accounting, project management, engineering, public policy, etc., results in a literature base that is fragmented in nature and awkward to consult. Moreover, there is little in the way of a common language or

terminology. For example, the terms technical risk, technological risk, and technology risk are used interchangeably and explicit definitions of these terms are the exception rather than the rule. It should also be noted that the articles referenced in this article, while representative of the literature, are drawn from a much larger body. (Hanlon, 2002) provides a more comprehensive review of this literature.

In an earlier work, (Hanlon, 2002) identified three themes in the literature, each reflecting a unique perspective.

Organizational

The first of these reflects an organizational perspective and tends to address issues that are strategic in nature and possess implications for the long-term viability and performance of the firm (Henricksen, 1997). The selection of the right development concept is of key importance to a firm (Reik, 2001), (Barclay and Dann, 2000). Several criteria have been proposed which attempt to predict a technology's future performance by examining the dynamics of technological change and the fit of the proposed technology with the external technological environment. Among these criteria are obsolescence (Henricksen, 1997), technical superiority (Duerr, 1986), product complexity (Barclay and Dann, 2000), and newness (Barclay and Dann, 2000).

The resourced-based view of the firm points to the importance of the fit between the technology and the organization's internal resources. According to one study (Duerr, 1986), fit or "compatibility" was second most frequently mentioned and also the second most important criterion (after profitability) used for evaluating ideas for new products or business ventures. In a more recent study performance was found to depend on whether the technology fit with the firm's existing marketing and technical competencies (Danneels and Kleinschmidt, 2001).

Some researchers, especially those interested in technology transfer have expressed a concern for the risk associated with the potential for inadequate ownership protection of technology. Once the right to ownership is established, an additional question becomes the extent to which ownership rights can be protected against infringement by competitors. Patents may also be used strategically to provide complementary protection for a core technology, to safeguard the right to participate in future variations of the technology, and to enhance the negotiating position in potential future alliances (Thumm, 2000).

Engineering

A second theme in the literature reflects an engineering perspective where the concerns tend to be with the technical feasibility of the project. (e. g., can a working prototype be developed), the reliability and control of complex systems, or safety - can potential damage to personnel and physical assets be minimized? Research on project management demonstrates the need for managing the risks associated with the development process, but often tends to be industry-specific (e.g. software development,

construction), making it unclear as to whether risk factors are generalizeable across industries. For example, Ben David and Raz (2001) present a quantitative model for risk reduction that integrates the project's scope into the risk management process, allowing a focusing on causes and effects of risk. An alternative approach from the construction industry incorporates fuzzy logic methodologies and information processing technology. Risk sources are identified, potential effects are quantified and procedures formulated for residual risks in the project (Tah and Carr, 2001). Schmidt, et al. (2001) have argued for the use of checklists in the assessment of project risks.

Societal

A third theme in the literature reflects the perspective of society at large and the stakeholder groups it encompasses. In this context risk concerns tend to be associated with the safety, reliability, environmental, and performance issues of a particular technology. The key issues to be addressed include, what can go wrong, how likely it is to happen, and the consequences if it does happen (Stevenson & Dooley, 1996). Although the assessment of objective risks is clearly important, people behave on the basis of perceived reality rather than on reality itself (Newby, 1997). The recognition of the role of public perception highlights the importance of risk communication in the framing of perception of risks. Key elements for success here involve the credibility and trustworthiness of the risk management process. Consequently, identifying and communicating with stakeholder groups is an important aspect of dealing with societal risk (Stirling 1999). Both scientific and precautionary approaches are important in assessing risk and a number of different stakeholder groups will exist for each potentially risky project. "Inclusive Deliberative Appraisal," involving a number of communicative techniques such as consensus conferences, citizens' juries and focus groups, has been suggested as an effective means of addressing the concerns of stakeholder groups (Stirling, 1999).

Overall, the risks identified in the literature have been summarized in a three-category framework represented by the following questions (Hanlon, 2002):

Organizational factors

A1. What are the future prospects for the technology?
A2. How strong is the fit between the organization and the technology?
A3. To what extent can ownership and protection of the technology be established?

Engineering factors

B1. Can the technology be developed... to meet specifications... on time... within budget?
B2. Can the technology be manufactured in a reliable, cost-effective manner?
B3. Can safety risks be managed within acceptable limits once implemented?

Societal factors

C1. What side effects, both real and perceived, exist and how severe are they?
C2. How powerful are the relevant stakeholder groups and how will they react?
C3. How well equipped is the firm to manage stakeholder relations?

A key question remaining, however, is the extent to which this organizing framework addresses the actual experiences of firms.

METHODOLOGY

For purposes of this research, small firms are defined as those with fewer than 100 employees. The firms included in the study were drawn from a database maintained by Strategis Canada, which provides contact information, names of key personnel, size by number of employees and by sales dollar category, and the company's most important product lines. The technologies included are information technology, software development, communications, industrial equipment and biotechnology. Ten firms located in the Calgary area were chosen for the study. One-on-one, relatively unstructured interviews were conducted with the president or founder of each firm. Careful notes were taken throughout the interview. The key pieces of information that the interviewee was asked to provide are:

- A description of the development process for the most recent product that the firm has brought to market, together with the significant milestones attained along the way. The entrepreneur was asked to walk the researcher through this process in his/her own words, with as little prompting from the researcher as possible.
- A discussion of the five most significant technology-based risks the firm faced during the development process. The entrepreneur was asked to describe the events leading up to the identification of each risk; the impact of the risk on the development process, the firm as a whole, and society at large; and what steps were taken to minimize the impact of the risk on each of these.

The entrepreneur was then presented with a list of potential risk factors that the researcher prepared from the tentative framework that was outlined above. Each was asked to point out any of these that were also identified and dealt with by the firm during the development process.

FINDINGS

In general the broad nine-category risk framework developed from the literature appeared to capture the scope of the risk identified by the firms. The qualitative coding procedure adopted, however, provided considerably more detail as to the specific nature of these risks. When the risk sources stemming from the literature review were combined with the interview results a total of 29 unique sources of risk were identified, consisting of 10 organizational risks, 14 engineering risks and 5 societal risks (Table 2).

{Table 1 about here}

Table 3 summarizes the number of firms reporting each source of risk. Both the solicitation of five most significant risks and the questionnaire were designed to measure whether or not a firm had encountered a particular source of risk. Neither, however, attempted to capture the potential for multiple occurrences within a single firm. Of the

29 risk sources identified, all but seven were identified as being one of the five most significant the firm faced. After the results of the questionnaire were included, however, all of the sources of risk had been identified.

{Table 2 about here}

Table 3 also indicates quite clearly that firms typically encounter many risks during the process of commercialization. A total of 186 risks were reported by the firms, with each firm facing 18.6 sources of risk on average. The sheer number of these encounters might seem to imply that the magnitude of the individual risks was not terribly great, but such was not the case. Although we did not formally measure the magnitude or importance of the risks, at least two factors tend to support their overall importance. First, it can be seen from a review of Table 2 that each source of risk is non-trivial and is associated with potential consequences sufficient to jeopardize the firm. Second, it was evident during the interviews that the firms considered the risks to be significant in nature. The obstacles they presented were neither easily nor quickly addressed and the difficulties that resulted often lasted for months rather than days or weeks, and in some cases endured for years.

Column four of Table 3 provides an indication of the relative prevalence of risk sources. Engineering risks tended to be the most frequently encountered type of risk, representing 48.92 percent of the total of 186 incidences. Organizational risks were the next most common, comprising 36.02 percent of the total. Finally, 15.06% of the risks identified were classed as societal. All firms in the sample faced organizational and engineering risks of some sort but societal risks were only encountered by eight firms, 80 percent of the sample. Initially it was suspected that this latter finding might be attributable to industry effects, but on closer examination it was discovered that all five industries sampled were indeed represented among the firms that had encountered societal risk.

{Table 3 about here}

The number and diversity of risks faced by firms is remarkable for at least two reasons. In one sense it is unsurprising, as the commercialization process is generally acknowledged to be difficult and associated with a high rate of failure. At the same time, 9 of the 10 firms had engaged in a formal planning process, which often included some combination of business planning, market planning, financial planning and technical feasibility or product planning. Five of the firms considered themselves to plan extensively. If planning is as pervasive as these firms suggest, one must wonder why firms still seemed largely unprepared and caught off guard by so many of the risks reported.

A comparison of columns two and three of Table 3 provides some insights concerning which sources of risk were more easily identified by firms. For example, of the three broad types of risk, organizational risks were the most reliably identified during the identification of the five most significant risk factors (phase one). Of the 67 sources

of organizational risk identified, 50.7 percent were identified successfully in phase one, without the benefit of the questionnaire. In contrast, the questionnaire (phase two) generated 75.8 percent of the total engineering risks and 89.3 percent of the total number of societal risks identified by firms. Several organizational risks appeared to be relatively straightforward to identify. A1.1 (is the market ready for the technology?), A2.1 (does the technology fall within the company's overall vision and long-term strategy?), and A3.1 (can intellectual property protection be maintained on a sufficient portion of the technology to block others from its use?), for example, stand out for having occurred frequently among firms. Interestingly, while engineering risks were the most frequently identified category overall, fully 75.8 percent of this came about as a result of the questionnaire and not during the identification of the most important risks faced by the firm. Only B1.3 (Are the design and development costs and timeframes predictable?) and B2.3 (Can the firm obtain components from outside parties that meet acceptable standards of reliability, availability and quality?) were identified as one of the most important by at least four firms. Finally, as noted above, societal risks were often overlooked in phase one, with several sources failing to emerge at all without the benefit of the questionnaire.

The firms in the sample ranged in age from 2 to 26 years (mean = 12.2years) and were relatively small. The average firm size was 22.1 employees and annual sales ranged from $100,000 to $4,000,000 (mean = $1,170,000). Table 1 provides a breakdown of the sample by industry.

The use of export markets as a means of growth was mixed. Two of the firms exported virtually all of their products, whereas five did not export at all, instead relying on domestic markets. Size of firm did not seem to be a factor in whether exports played a significant role – the two exporting firms were among the largest, but two of the non-exporters were equally large. For six of the firms, the commercialization project addressed in the interview represented the firm's sole source of revenue. Two of the remaining four firms, however, had already developed additional commercial products. Interestingly, the two remaining firms had initially been formed to commercialize the product that was the subject of our investigation. However, in order to generate adequate cash flows during the commercialization process these firms had developed extensive consulting practices that had become the focal point of the business, relegating the commercialized product to secondary status.

DISCUSSION AND CONCLUSIONS

Despite significant variations in the size and age of the firms included in the study, and the fact they are drawn from a number of industries, there was a remarkable level of agreement among participants that technology-based businesses do encounter unique sources of risk not normally faced by firms operating in other industries. Although the study did not include a comparison group drawn from more traditional industries, the sheer number and variety of sources of technology-based risk identified during the study reinforced participants' view that they did, in fact, operate in a riskier environment than other firms. To some extent, this might be categorized as a question of

degree rather than uniqueness. For example, many firms in non-technology-based industries face issues associated with matching the selection of new opportunities to the firm's competencies, or the difficulties of establishing budgets and timelines when bringing new opportunities to fruition. There was a sense, however, that developers of new technologies see these sources of risk as having higher potential to cause severe problems for the organization, in part because of the longer developmental time frames, the difficulties associated with developing reliable prototypes, and the possibility that the market may have shifted to a competing technology in the interim.

Many of the firms interviewed stated that they did extensive planning, and that planning was a key factor in dealing with sources of risk. At the same time, many of the firms regarded the formal business plan as an inappropriate tool for internal use and expressed a lack of confidence in its effectiveness. For example, the founder of one firm in the information technology sector stated that the formal business plan that he had prepared at the early stages of his business proved so unrelated to the activities that he found necessary to maintain his business that for a period of time he did almost no planning at all. He has since completed a proposal for venture capital funding, and while he sees the value of the business plan in that context, he remains unconvinced of its usefulness as an internal guide for operations. Instead, he prefers to work with very short term operating plans that will provide a map for developmental activities. Indeed, a number of firms stated that business planning had generally been undertaken to satisfy the needs of outside financing agencies.

It was somewhat surprising to note that interviewees tended to identify organizational issues as the most important faced by the firm. Based on this, and the relatively short-term focus of much of the planning that takes place in the firms, it would appear that in many cases the managers of these firms have the ability to also operate in the context of longer-term issues. This ability to marry the long and short-term issues associated with the firm bodes well for the eventual long-term success of the enterprise. Only two of the firms identified societal issues as being of major importance to its success. During completion of the questionnaire, however, participants tended to focus more on these issues. It would appear that while the firms did acknowledge the importance of the potential impact of sources of societal risk, these are probably not the main focus of the firm's planning.

The firms studied considered the research to be highly relevant to their needs. In general, firms exhibited a high level of interest in participating and were extremely interested in receiving the results. On a number of occasions during the interview process, interviewees expressed frustration with the fact that there were no clear guidelines available to assist them with the identification, assessment and management of technology-based risks. This was particularly true of the younger firms in the survey, one of which pointed out the plethora of business planning guides available from a variety of sources, and decried the lack of similar products for use with technical projects. None of the participants had developed written criteria for the selection and development of new products. Instead, this was largely the result of trial and error over a period of time. This finding is consistent with other research suggesting that while there may be tools

available, they often do not meet the needs of small firms (Hanlon, 2002) and do not reflect the way in which individuals think about risks (Shapira, 1995).

Many of the sources of risk reported by the interviewees do not fit into the traditional marketing and financial risk categories faced by virtually all firms. In fact, the author concludes that although firms operating in other, more traditional industries may face some of these risk sources, the sheer frequency of reporting indicates that they are far more critical in small, technology-based firms. It appears that there is a set of distinctive risks that these firms face in addition to those faced by more traditional firms. Moreover, the analytical framework emerging from the research appears promising in that it is capable of capturing risks across a range of industries yet is not encumbered by idiosyncratic risks particular to one firm. The findings must be understood within the context of the study limitations, however. Of primary importance are the limitations associated with the sample design. First, the study did not include failed firms or even failed projects in the sample. Second, the sample is quite small. Finally, only five industries were examined. All of these limitations, however, appear reasonable in light of the exploratory context of the investigation and the concatenated nature of the larger research program (Stebbins, 2001).

The findings, though tentative, also hold promise for practitioners such as entrepreneurs and investors, who stand to benefit from the development of stronger assessment tools for the identification and assessment of risks. However, future research is needed to establish the generalizability of the findings and to investigate how firms actually manage these risks as they arise.

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Table 1
Sample Distribution by Industry

Industry	# of Firms	% of Firms
Information Technology	4	40.0
Communication	1	10.0
Electronic Components & Instrumentation	2	20.0
Industrial Equipment	1	10.0
Biotechnology	2	20.0
Total	10	100.0

Table 2
Risk Sources

Organizational Risks	
A1.1	Is the market ready for the technology? i.e. does the market perceive the value of the technology?
A1.2	Do the functions of the technology match the needs of the market?
A1.3	Is the technology prone to rapid obsolescence?
A1.4	Are there wholly different technologies that are capable of meeting the same need?
A1.5	Does the product have to interface with a broad variety of existing other technologies characterized by a lack of standardization & consistency?
A2.1	Does the technology fall within the company's overall vision and long-term strategy?
A2.2	Is the product consistent with the company's competencies?
A3.1	Can intellectual property protection (e.g., patent) be maintained on a sufficient portion of the technology to block others from its use?
A3.2	If property rights to all or part of the technology are held by others, does the firm have unrestricted access?
A3.3	Is the product technically complex and difficult to duplicate by competition?
Engineering Risks	
B1.1	Does the firm have ready access to the skills needed for design and development of the technology
B1.2	Can the firm select and control those responsible for sub-contracted portions of design & development?
B1.3	Are the design and development costs and timeframes predictable?
B1.4	Are there regulatory requirements or standards that govern the technology?
B1.5	Are regulatory requirements and standards consistent both among regulatory agencies and over time frames?
B1.6	Could a working prototype be developed?
B1.7	Was the technology over-engineered?
B1.8	Does the design reflect ease of use and maintenance?
B1.9	Are technology specifications constantly changing?
B2.1	Can the firm produce the technology at cost & quantity levels that permit a satisfactory return on investment?
B2.2	Can the firm maintain acceptable quality standards?

B2.3	Can the firm obtain components from outside parties that meet acceptable standards of reliability, availability and quality?
B2.4	Can the firm control the frequency and degree of customization required by customers?
B3.1	Can the firm maintain acceptable safety standards during the production process?
Societal Risks	
C1.1	Can the firm identify actual potential side effects associated with the technology?
C1.2	Can the firm identify potential side effects that might be perceived by the public?
C2.1	Can the firm identify stakeholder groups that could potentially impact the acceptability of the product?
C2.2	Can the firm predict the extent to which acceptability might be impacted by these groups?
C3.1	Can the firm initiate and maintain working relationships with key stakeholder groups?

Table 3
Sources of Risk by Frequency of Occurrence

	Phase 1 (Five most significant)	Phase 2 (Questionnaire)	Total
Organizational Risks			
A1.1	6	4	10
A1.2	3	5	8
A1.3	1	2	3
A1.4	1	4	5
A1.5	3	2	5
A2.1	6	1	7
A2.2	4	5	9
A3.1	5	4	9
A3.2	3	2	5
A3.3	2	4	6
Subtotal	**34**	**33**	**67**
Engineering Risks			
B1.1	2	7	9
B1.2	3	4	7
B1.3	4	5	9
B1.4	1	4	5
B1.5	2	2	4
B1.6	1	6	7
B1.7	0	4	4
B1.8	0	4	4
B1.9	0	4	4
B2.1	2	5	7
B2.2	0	8	8
B2.3	4	3	7
B2.4	2	8	10
B3.1	1	5	6
Subtotal	**22**	**69**	**91**
Societal Risks			
C1.1	2	6	8
C1.2	0	6	6
C2.1	0	5	5
C2.2	0	5	5
C3.1	1	3	4
Subtotal	**3**	**25**	**28**