Towards a Classification of Technology Strategy Frameworks

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Abstract: The formulation of a technology strategy is a critical first stage in the process of managing technology inside organizations. Numerous technology strategy frameworks have been proposed in the literature to provide structure to the communication of complex ideas and to contribute to the traceability and transparency of information flows during the strategic decision making process. This research field has evolved considerably in the last decades and the varied contributions indicate a need for a novel classification to support the identification of relevant topics for further research. This paper presents a review of a number of technology strategy frameworks from the scientific literature. These frameworks are analysed according to the attributes (conceptual, applied, static and dynamic) of a meta-framework proposed by Shehabuddeen et al. (2006) aimed at improving the understanding of management frameworks. The frameworks are also analysed through the lens of two prominent schools of strategy: the positioning and resource based view schools. Based on the interpretation of underlying concepts and ideas, the reviewed frameworks are positioned in a three dimensional chart where two axes portray the attributes of the meta-framework and the remaining axis, the opposing schools of strategy. The classification of the reviewed frameworks in divergent axes suggests a dichotomous approach that has been followed in the development of technology strategy frameworks, where new developments attempt to challenge the ideas of previous models. The proposed classification also extends previous models, namely by Arasti and Packniat (2006). In the case of applied frameworks, their observation also revealed that the technology strategy formulation process has been consolidated into four core activities, each one of them encompassing a number of applicable tools. This investigation demonstrates the increasing centrality of the resource based view paradigm in the development of technology strategy frameworks, which can indicate a change in the perception on how organizations compete in technology markets. This paper also highlights the relevance of research on technology management methods and tools and the extent to which these contribute to the management of information and knowledge flows and to the decision-making capabilities of organizations. Future research should focus on the incorporation of additional attributes to provide a more comprehensive classification model of technology strategy frameworks, and also investigate the applicability of the proposed classification model in other management frameworks.

Keywords: technology strategy, framework, classification, resource based view

1. Introduction

Technology is widely recognized as a fundamental cornerstone for the competitiveness of companies through several mechanisms, such as in creating entry barriers, attracting new customers and markets and even changing the rules of competition in an industry (Zahra, 1996).

The operationalization of technology strategies has been made possible through frameworks that assist organizations in understanding the driving forces that influence the technology strategy formulation process as well as present possible process and activity structures. The formulation of a technology strategy depends on multiple information flows and, in this sense, the evolution of information technologies has provided unprecedented contributions in storage, cross-analysis and dissemination capabilities of strategic information in organizations.

This study is motivated by the apparent lack of classification models of technology strategy frameworks that support an understanding of the nature of such frameworks and thus shape the development of future strategic information systems. This article presents a historical overview on a set of technology strategy frameworks proposed in the literature, and proposes a new classification model based on a management meta-framework and two prominent strategy paradigms in order to identify contemporary research topics.

This paper is structured as follows: section 2 presents the literature review about technology strategy, frameworks and information needs, section 3 describes the research methodology, section 4 describes the analysis performed on a number of technology strategy frameworks, section 5 introduces the proposed classification model, and section 6 presents the final conclusions of this study.

2. Literature review

2.1 Technology strategy formulation

Nowadays, the concept of technology strategy encompasses a broader perspective on technology, from a purely technical viewpoint to including organizational, business and societal issues and, consequently, sourcing ideas from diverse disciplines. A technology strategy can be simply defined as the approach followed by organizations in using technology to build new (offensive) or sustain (defensive) competitive advantages (Porter, 1983, Chiesa, 2001, Burgelman et al., 2003).

Different strategy paradigms have influenced the technology strategy constructs proposed in the literature. Two of the foremost paradigms are the positioning school and the resource based view (Chiesa, 2001). The positioning school advocates that the most successful companies are the ones that position themselves in environments where they can enjoy sustainable competitive advantages (Porter and Chandler, 1985, Hax and Majluf, 1991). This school of strategy is centred on the analysis of business environments, in which technology is a critical dimension. The resource based view proposes that organizations should specify a resource profile, which includes managerial capabilities and technological competencies (Walsh and Linton, 2001, Marino, 1996) to enable optimal product-market activities (Wernerfelt, 1984, Prahalad and Hamel, 1990, Bone and Saxon, 2000).

The content of a technology strategy program is related to a set decisions including the selection of technology(ies), acquisition modes, timing of introduction of technology, required resources, capabilities and competencies and the organization and management approach of technology and innovation (Porter and Chandler, 1985, Hax and Majluf, 1991, Chiesa, 2001, Lindsay, 2001, Burgelman et al., 2003)

2.2 Frameworks and information needs in technology strategy formulation

Frameworks have been developed by scholars and practitioners to facilitate the understanding and communication of structure and complex relationships within systems (Shehabuddeen et al., 2006, p. 325). According to Centidamar, Phaal and Robert (2010), technology management frameworks – of which technology strategy formulation is an integral part – have two basic elements: *activities* and *tools*. Activities are management process, routines and organizational tasks implemented in organizations to support the management of technology. Tools are techniques and methods used to carry out such activities and make sense of the multiple information streams.

Technology strategy frameworks have been consolidated into five core activities (Ford, 1988, Chiesa, 2001, Burgelman et al., 2003): *internal analysis* – identification and analysis of inner organizational technological capabilities – *external analysis* – examination of relevant (for the organization) future technological trajectories and of the role that markets, customers' needs and events have in shaping these trajectories – *generation* – generation of project ideas and proposals, based on the strategic guidelines provided in previous analyses – *selection* – deciding on which strategic technology projects to invest in – and *reflection* - an analysis of the results achieved in the implementation of a strategy *vis-à-vis* the initial goals set. There are a large number applicable tools and methods to each of the aforementioned activities, from simple management consultancy charts and exercises to more sophisticated mathematical formulations and search analysis algorithms.

Information systems have an increasingly determinant critical role in technology strategy formulation, in at least two ways: 1) in providing basis for the documentation of plans, instructions and controlling mechanisms (Näsi, 1999) and 2) in enabling the cross analysis of data and information from multiple sources for the purpose of improving an organization's understanding of a particular situation. The latter has been conceptualized under the name of Technology Intelligence (TI) systems, and defined as *"the capture and delivery of technological information as part of the process whereby an organization develops an awareness of technology threats and opportunities"* (Kerr et al., 2006, p. 75). This definition suggests the TI systems architectures comprise features that include databases, tools and applications to enable the storage and analysis of large amounts of data and also applications that dissemination of information among group members.

The contribution of TI systems lies in overcoming human limitations with respect to the analysis of large amounts of data and in improving communication and collaboration. And as management decision making is increasingly information intensive activity, the boundaries that seemed to separate decision support systems from TI systems are now merging (Skyrius et al., 2013). Moreover, information technologies have an empowering role in building on the complementarity of the positioning and resource-based view approaches to strategy (Rivard et al., 2006).

The information to be contained depends on the investment requirements to acquire data, their availability, organizational emphasis and preferences on a selected number of indicators, among other factors. Notwithstanding this and according to Santos (2014), the information needed for selecting technology development projects are intrinsically related to the criteria used to compare project proposals. Based on review on selection criteria, Table 1 illustrates a number of information needs and typical information sources that can feed TI systems.

Table 1 – Information needs and sources in the technology strategy formulation. Source: (Santos, 2014)

Information needs	Typical information sources
Previous experiences and lessons learned with similar technology development projects.	Internal projects reports.
Availability of resources and technological capabilities.	Human resources databases. Equipment inventories.
Availability of complementary assets (distribution channels, manufacturing process, etc.)	Networking, industry publications.
Trends (technology, society, environmental, market and others) and events likely to influence technological trajectories.	Scientific publications, patents, expert opinions, industry publications, special reports, magazines, etc.
Analysis of the scientific basis and originality of the research.	Scientific publications.
Technical risks.	Feasibility tests, lessons learned from previous projects.
Protection of intellectual property	Patents and copyrights databases.
The possibility of setting standards	Patents databases, competitors Benchmarking reports.
Stage in technology life cycle.	Market reports, industry publications.
Economic attractiveness.	Market reports and industry publications information (size, growth rates and competition). Business plans describing estimated project and manufacturing costs, pricing decisions, etc.
Matching of customers' needs and suitability of planned timing of introduction.	Customers' surveys, interviews, market and industry publications.
Differentiation level achievable.	Customers' surveys, competitors'' products benchmarking reports, market and industry publications.

Potential for technologies and products range growth in the organization.	Technologies applications tests.

As information technologies are increasingly perceived as enablers of strategy and performance (Henderson and Venkatraman, 1999), it becomes critical to understand the foundations of strategy, namely its implications to the development phases of information systems research in this area (Hevner et al., 2004). Research on strategy is complex and has been influenced by a number of paradigms over time. Despite large number of contributions in the literature, there is a lack of studies that contextualize the evolution of technology strategy frameworks. Studies of this kind could contribute to the design of future information systems that support the formulation of technology strategies, that is, on their suitability to the new forms of organization, implementation models and practices. This study fills this research gap.

3. Methodology

The research methodology applied in this study involved, in a first stage, a review on technology strategy frameworks from scientific literature and, in a second stage, their categorization into a classification model for the purpose of improving the understanding about the nature and evolution of technology strategy frameworks. In this sense, the researcher assumes an interpretative role using as basis an analytical framework (the classification model).

The classification model is based on the meta-framework developed by Shehabuddeen (2000), in a response to criticisms about the lack of rigor and consistency in the definition, development and implementation of management frameworks. According to the referred meta-framework, there are two dimensions that characterize management frameworks, which basically represent dichotomous attributes: applied-conceptual and static-dynamic. The first dichotomy represents the nature of the relationship with the environment described by the frameworks, while the second dichotomy represents the nature of the relationships between the elements described in the frameworks.

In an attempt to propose a more comprehensive classification model, this study considers the two dimensions of Shehabuddeen's meta-framework (conceptual versus applied and static versus dynamic) along with the schools of strategy (positioning and resource based view) to categorize technology strategy frameworks. It is understood that these dimensions and schools of strategies have a dichotomous nature which has been instrumental in technology strategy frameworks' underlying philosophies and foundations.

In sum, technology strategy frameworks are classified according to the dichotomous attributes and schools of strategy described as follows:

Dichotomy1 (nature of the relationship with the environment):

- Conceptual: frameworks that depict an abstraction or an understanding of a situation;
- Applied: frameworks that address practical implementation issues in real environments.

Dichotomy 2 (nature of the relationships between the elements in the framework)

- Static: frameworks that portrays the structure and position of elements (maps, models, processes, procedures, techniques and tools) within a system;
- Dynamic: frameworks that describe interactions between the elements of a system.

Dichotomy 3 (school of strategy):

- Resource based view: frameworks that support the idea that the starting point of the formulation of technology strategies should be the internal analysis of the organizations' technological competencies and capabilities;
- Positioning view: frameworks that support the idea that the starting point of the formulation of technology strategies should be the external analysis on technological trends and other external drivers that might influence the trajectories of technologies evolution.

The classification described in this study extends the one proposed by Arasti and Packniat (2006) which categorized technology strategy frameworks with respect to which school of strategy they belong to (positioning or resource based view) and their perspective on the formulation of a technology strategy (incremental or rational). Some frameworks presented in this study advance from the conclusions of the analyses from Arasti and Packniat's classification model (Porter's, Ford's , Hax and Majluf's and Chiesa's) other are new additions in this study (Du Preez and Pistorius's and Davenport's), as is described in the next section. Unlike Arasti and Packniat, this study presents an analysis on frameworks of the scientific literature only.

4. Analysis of technology strategy frameworks

An early attempt of framing technology in corporate strategy is proposed by Porter (1985). Technology is seen as a determinant of industry structure and a critical factor in generating sustained competitive advantages for companies. Porter proposed a structured approach to technology strategy development: 1) identification of technologies in the company's value chain; 2) identification of relevant technologies available in other industries; 3) definition of likely patterns of technological trajectories; 4) definition of key technologies for the company to obtain and sustain competitive advantage; 5) valuation of the company's capabilities and required investments in technology development and 6) definition of a strategy to support the company's competitive position.

Porter's framework aligns with the positioning school, given the emphasis put on technological change rather than on internal capabilities and competences of the company. It is also a static and applied framework, such is the multi-stage process for technology strategy formulation.

In the framework proposed by Ford (1988), technology strategy formulation is supported by three core activities: acquisition, management of technologies and exploitation. An internal audit is also proposed to support the development of a technology strategy. The audit consists of a number of questions aimed at helping companies to reflect on their potential for the development and exploitation of technologies, among other relevant issues.

Although somewhat unclear, it can be said that Ford's framework follows the positioning school, since the focus of analysis is predominantly the technology, rather than the organizations resources and capabilities. The framework only describes generic activities (acquisition, management and exploitation) but the relationships between them are not clear. Furthermore, such activities are more related to decisions rather than specific processes. As such, it is a conceptual framework, and also dynamic, given the iterative role of technology management in the process.

A linear process approach was proposed by Hax and Majluf (1991). The link between technology and business strategy is emphasized in this framework, which characterizes the primary tasks that are relevant in the development of a technology strategy. The process begins with the identification of technology requirements that align with the strategy of the company, first at a corporate and then at a business level. The next tasks concern the identification of technology trends ("technology environmental scan") and of internal technological strengths and weaknesses of the company against its competitors ("technology internal scrutiny"). The attractiveness and strength of each strategic technology unit is then assessed through a technology portfolio matrix tool, and opportunities and weaknesses are identified. Finally, broad and specific action programs, budgets and re-evaluation policies are established in the last stages of the process.

Hax and Majluf's framework considers both the internal and external environments, so it is not clear to which strategy school it belongs. It can be said though, that since the focus is on technology rather than competences, the framework leans forward to the positioning school. The explicit step by step process, depicting specific activities, clearly characterizes an applied and static framework.

The need to explore other driving forces derived from the political, economic and social domains, beyond the typical technology-market interaction, is an issue that should be addressed, according to du Preez and

Pistorius (1999). They proposed a structured framework for assessing technological threats and opportunities. This framework highlights the information requirements in the earlier stages of the process, namely on scanning and monitoring the dynamics of the environment, organizing and classifying this information. This information should feed a series of analyses using, for this purpose, established techniques and tools. Next, opportunities and threats are assessed, along with audits conducted on organizational capabilities and analyses on the interaction between technologies and market applications.

Du Preez and Pistorius's proposition considers both internal and external environments in the process, but the focus of analysis is still the technology and the environment, such as the emphasis put on "scanning" and "monitoring" activities. Therefore, the framework leans towards the positioning school. The structured process suggests that it is an applied framework. Finally, the framework implies a more dynamic approach since it provides a strategic reflection activity that enables the adjustment of the strategy in light of new information and events.

The need to consider the dynamics of competitive environments with the development of a technology strategy is highlighted by Chiesa (2001). According to the framework proposed by Chiesa, information must be gathered to answer three key decisions: selection, timing and acquisition. For this purpose, the author proposes what he calls the *context foresight process*. This process consists of two types of analyses: the external and internal context driven analyses. In the end of this process, a technology-application matrix is built, which serves as basis for defining broad technology strategy programs.

The output of this process is a match between the internal and external analysis, which means the identification of a technological skill base that is necessary for the company to obtain competitive advantage. As a result, there are five types of technology strategy actions: competence deepening, competence fertilizing, competence complementing, competence destroying and competence refreshing. Each of these strategies is appropriate according to the novelty of technologies and applications to the organization.

Chiesa's framework, centred on internal competences, suggests a resource based view approach. The context foresight process consists in two types of analysis (internal and external) which feed a technology versus application matrix and implies a structured process to support the decisions of the technology strategy formulation (selection, acquisition and timing), which are related to each other. Therefore, it can be classified as an applied framework. Finally, because of the dynamic nature of the possible strategic actions, it can be said that this is a dynamic framework.

In line with Ford's framework, Davenport et al. (2003) also argued that the formulation of a technology strategy revolves around three activities: acquisition, management and exploitation. However, they extended the framework to include a number of other contributing components beyond just technology, namely the technological knowledge and the learning capability of organizations. This framework highlights the role of external networks and the acquisition modes in nurturing internal technological competences and capabilities of organizations. Therefore, it may be said that it is centred in the resource based view school of strategy. Additionally, and as with Ford's framework, it is a conceptual and dynamic framework as it emphasizes the iterative role of continuous learning in the strategy process.

Burgelman et al. (Burgelman et al., 2003) observed the technology strategy development as a learning process. Experience and learning play a critical role in defining a technology strategy, and a structured process is not proposed. It is more related to the resource based view school of strategy, given the relevance of organizational competences in developing a strategy. It is also a conceptual framework, as no sequence of activities or structured process is described and importance is put on the driving forces of the technology strategy formulation process. Therefore this framework can be understood as a dynamic framework, since it considered the influence of internal and external environments in shaping a strategy and, emphasized the strategy learning process.

5. Proposed classification of technology strategy frameworks

The analyses presented in the previous section provide basis for the classification in a three dimensional chart, as shown in Figure 1. The placement of each framework in the chart does not mean a greater or lesser extent in each dimension. Table 2 presents a brief description of each framework and their categorizations.

An important observation in the analysis is the predominance of the resource based view in the latest contributions. This suggests that the analysis of internal technological competencies and capabilities should be the starting point of the technology strategy formulation process. This can be explained by the increasing relevance that environmental dynamics has in strategic management literature, materialized in the concept of dynamic capabilities (Teece et al., 1997). According to these ideas, organizations are only capable of developing a limited knowledge about their environment, which is constantly changing. The inherent uncertainty of market dynamics would lead to continuous realignment of market-based strategies. As such, a strategy based on resources presents appears as the most robust perspective since it is based on the development of internal technological competencies and capabilities that can give rise to many different applications, which can then be exploited as soon as a market opportunity is envisioned.

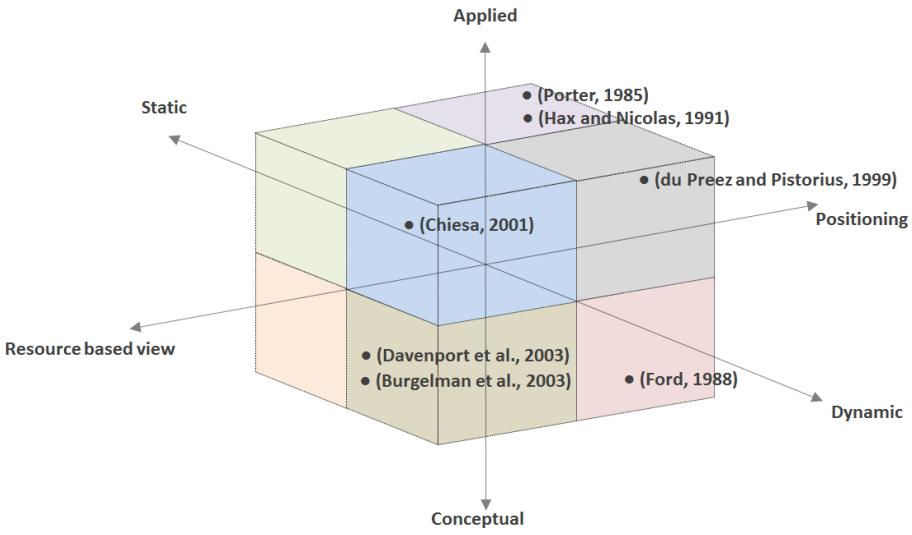

Figure 1 – Three dimensional classification of technology strategy frameworks

The predominance of recent dynamic frameworks goes in line with the increasing importance of the resource based view. Authors are more interested in the analysis of the interactions between elementary activities, of the process and forces that determine technology strategy decisions rather than proposing optimal or near-optimal procedures for strategy formulation adjustable to any organization, under the argument that structured processes may cause organizational rigidities, which may be a counter-productive approach in dynamic environments. The same reasoning also applies for explaining why authors are given more emphasis to conceptual than to applied frameworks.

The analysis reveals an emphasis in the role of dynamic environments, a reality that is increasingly present in a large number of industries, where technological paradigms have shorter lifetimes, and therefore technology itself no longer plays a primary role, leaving room for analysis based on core competences. The positioning school is only appropriate in industrial contexts with well-defined boundaries and where the products' required levels of performance are known, and for this reason there is nowadays a greater tendency to consider the internal perspective, or the resource based view in technology strategy.

Events outside the technological domain, such as in the market, economy, regulations and society domains, should also be considered in technology strategy formulation, since they may represent both opportunities

and threats to the development and diffusion of new technological solutions. The observed dichotomies represent extreme perspectives and efforts in bringing some logic to this complex theme. The design of information systems to support technology strategy is challenged by the requirements of organizational flexibility to adjust to changes in the environment and in handling and enabling the analysis of multiple sources of information.

Table 2 – Summary of technology strategy frameworks and their categorization

Reference	Short description	Framework categorization
(Porter, 1985)	Essence of strategy is to position companies in favourable competitive environments.	Positioning, applied and static.
(Ford, 1988)	Technology strategy development is supported by three core activities.	Positioning, conceptual and dynamic.
(Hax and Majluf, 1991)	Link between technology and business strategy is emphasized in the framework.	Positioning, applied and static.
(du Preez and Pistorius, 1999)	Exploration of forces beyond the typical technology-market interaction.	Positioning, applied and dynamic.
(Chiesa, 2001)	Consideration of the dynamics of competitive environments in technology strategy.	Resource based view, applied and dynamic.
(Davenport et al., 2003)	Highlights the role of external networks in the learning capability of organizations.	Resource based view, conceptual and dynamic.
(Burgelman et al., 2003)	Technology strategy development is understood as an organizational learning process.	Resource based view, conceptual and dynamic.

The applicability of the proposed taxonomy can be envisioned in the way that it may elucidate the directions taken by organizations in the formulation of their technology strategies. In other words, it can help explain how different industrial sectors tend to apply certain processes and methodologies and how context influence such preferences. Cross-sectoral empirical studies may be used to validate the taxonomy.

6. Conclusions

This study contributes with a novel classification model of technology strategy frameworks. It attempts to bridge two branches of literature, namely in understanding how management literature can contribute with theories, frameworks and building blocks to the strategic information systems.

This classification has important implications to the way information is managed in the formulation of technology strategies. The foremost one is the requirement for TI systems to include *"incrementalism"*, i.e. allowing modifications and adjustments in light of new information. Thus, the design of TI systems should feature modules that enable the traceability of assumptions, estimates, judgements and premises made in earlier stages can be revised and used to improve the decisions in future strategic cycles.

Another implication is that, since strategy formulation is mostly a collaborative effort, transparency in the connections between activities and in information flows should be ensured so that the process is understood by all participants, thus having engagement effects, and a shared platform exists in the organization. Finally, TI systems should be designed with a clear and logical progression towards strategic decision-making, where analyses precede decision-making, without neglecting the need to introduce flexibility, translated in the uncertainty inherent to technological developments.

Despite the extensive review, more recent technology strategy frameworks could not be found in literature. The analysis of the frameworks is limited, as expected, by the researchers' interpretation of what is described by the proponents of the frameworks. Future work should focus on investigating the applicability of the proposed classification model in other management frameworks. Additionally, should focus on the other component of information systems infrastructure, beyond activities: tools. Studies can approach which kind of tools better suits to the most prominent strategy paradigms, what opportunities for combinations of tools exist to improve analysis and decision making and what tools incorporate uncertainty management in their potentialities.

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