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An Organizational Capability-Based Performance Measurement Model for Technology Conversion Process

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Abstract

The capabilities reconfiguration theme is presented in contemporary literature as a useful approach to business-model adjustment for the conversion of new technologies into processes, products, and services. This work presents a proposal for operationalization of this concept, developing an organizational capability measurement and evaluation model in the process of technology conversion in products and services. Applied to an enterprise started by an academic 'spin-off' company located in Brazil, the model presented as suited to the promotion of several relevant debates regarding capabilities evaluation, development, and cooperation, with the aim of creating an adequate organizational structure.

Keywords: Organizational capability, technology-based companies, technology management, product development, performance measurement model

JEL Classification codes: M10, M13, L23, O32, L25

The evolutionary theory of the firm, and the capability-based view (CBV, also called competence-based view and dynamic-capability view), is designed to support decision making by management inside companies, especially in the context of technology-based companies. It describes the firm's dynamic capabilities and organizational capabilities (re)configuration process with the aim of helping develop the capabilities suited to the internal and environmental needs (Boccardelli & Magnusson, 2006; Helfat & Peteraf, 2003; Helfat et al., 2007; Laamanen & Wallin, 2009; Nooteboom, 2000; Mustar et al., 2006; Sanchez, 2008; Sanchez & Heene, 2010).

Organizations grow and change by reconfiguring their routines and capabilities. The product-development process, as the main change operator of the continuous adaptation process, constitutes a dynamic capability that enables organizational growth and evolution. It delinks existing capabilities and re-links them in order to enable the development, manufacturing, and distribution of new products and services. As a result, the business model evolves progressively through several testing and decision-making processes, resulting sometimes in migration to another organizational structure (Amit & Zott, 2001; Chesbrough & Rosenbloom, 2002; Danneels, 2002; Eisenhardt & Martin, 2000; Helfat & Peteraf, 2003; Kleinschmidt, Brentani, & Salomo, 2007; Leonard-Barton, 1992; Nelson & Winter, 1982; Penrose, 1959; Teece, 2010; Zahra, Sapienza, & Davidson, 2006).

A concordance has been observed between some theoretical approaches to product development, strategic technology management process, and strategic managing, including business-model research lines. The research into new product development (NPD) management indicates that different structural configurations (business model, organizational architecture) are related to different strategic results (Aldrich & Ruef, 2006; Mathews, 2006; Williams, 2008). The discussions on business-model and organizational-architecture themes, frequently observed in the literature related to technology-based companies (Vohora, Wright, & Lockett, 2004), emphasize the business model as an enabler of the firm's development, by capturing value from the technology, as it facilitates representations of the firm's or enterprise's architecture. Because of the detailed planning and organizational learning process involving decision making at all levels of companies, business models need the definition of their descriptive units to aid implementation. One of these components or descriptive units is organizational capabilities (Chesbrough & Rosenbloom, 2002; Magretta, 2002; Morris, Schindehutte, & Allen, 2005).

Considering these theoretical grounds, the NPD process is understood as a capability portfolio (re)configuration process (Atuahene-Gima, 2005; Danneels, 2002; Eisenhardt & Martin, 2000; Kleinschmidt et al., 2007; Leonard-Barton, 1992; Paladino, 2007; Pavlou & El Sawy, 2004; Wernerfelt, 2005; Zahay, Griffin, & Fredericks, 2004). The CBV allows a value chain-based, long-term vision because it is focused on growth and change. Hence, companies that incorporate evaluating organizational capabilities into management decision making gain competitive advantages in the medium and long term (Amit & Zott, 2001; Capron & Mitchell, 2009; Chesbrough & Rosenbloom, 2002; Teece, 2010). Some strategic analysis practices, such as the capability-based planning (CBP) used in the military area, take advantage of this approach. Thus, the CBV of the firm presents some practical applications in managing the company growth and the achievement of competitive advantage. Nevertheless, the following question is already in discussion: "How should the process of organizational capabilities reconfiguration inside companies, with commercial intents, be conducted?"

This paper presents the result of research into developing a capability measurement and evaluation model as an operationalization of a strategic decision-making model. The research embraced the concepts and "insights and options suggested by the Resource Based View … which, along with the area of dynamic capabilities, promotes an inside-out view of strategy making" (Ackermann, 2011, p. 921). The aim is to develop a strategic decision model that employs the use of the views and beliefs of managers and which structures the decision process, enabling them to plan or manage complex systems (Hitchins, 2008; Jelinek, Romme, & Boland, 2008).

In the next section, the model is presented, initially by its incorporated conceptual basis and then by its structure. The theoretical and conceptual basis of the model is comprised of concepts for capability evaluation, mainly originating from CBV-related literature, which describe or discuss the capabilities (re)configuration process and definition of the business model for products and services commercialization in technology-based companies. The conceptual map of the constructs of organizational capabilities evaluation was designed as result of gathering of these concepts, and it structures its estimation by representing the relationship of the model's metrics. The model also offers the index-obtaining structure, a metrics scores-combining method definition. Finally, a case study is presented, showing the applicability of the model, the main results, and the discussions generated.

Conceptual Basis of the Model

The main concept behind the model is that of *organizational capabilities*. Organizational capabilities are configured as high-order organizational processes, comprised of abilities converted into repeated activities. These repeatable patterns are defined as *heuristics* or *routines*. These activities or routines present inputs and outputs, which can then be defined to enable the management to use them as options for decision making, with the aim of generating significant and specified outputs. Capabilities enable the firm to deploy resources, usually in combination, using organizational processes to obtain the expected results. They evolve and are developed, in time, by complex interactions between the firm's tangible and intangible resources. They are based in the development of human capital, by use and change of information. They can be developed in the functional area or by combining the human, physical, and technological resources within the company or in association with other companies (Amit & Schoemaker, 1993; Bingham, Eisenhardt, & Furr, 2007; Eisenhardt & Martin, 2000; Helfat & Peteraf, 2003; Nelson & Winter, 1982; Teece, Pisano, & Shuen, 1997).

The CBV is applied to the value network concept. The capabilities are considered as ways to add value to the final customer product, and they transcend the limits of the company. The focus of analysis is the all-value constellation, for which decisions are made to allocate investments in resources and routines, ensuring the integration of prime capabilities by considering the value-adding likelihood, without straining the companies' limits (Hubbard, Zubac, Johnson, & Sanchez, 2008). For this reason, the model evaluates the enterprise, even if conducted by only one company or by a conjoint of companies, including the suppliers and other intermediates, that is, the all-value adding chain.

CBP is a practice that explicitly applies the CBV. The CBP presents some similarities with several product-development process models: It is an approach consisting of cycles of deployment and refinement. Instead of just converting and deploying the market needs into requisites and specifications, the CBP starts from the capabilities definition. This is allocated in a stage previous to the market-needs definition. These capabilities are deployed in needs, requisites, and specifications. This view includes the concept of volatility of the requirements and enables change-tolerant planning. The requirements and specifications of products, components, processes, services, and resources are altered with the change, and an improved understanding of the industrial, economical, technological, cultural, and market environment evolves. The capabilities are regarded as the constant in this evolution (Davis, Shaver, & Beck, 2008; Desgagné, 2009; Jamshidi, 2008; Matisoo, 2008; Neaga, Henshaw, & Yue, 2009; Pennie, 2001; Stevens, Brook, Jackson, & Arnold, 1998; Tagarev, 2006).

Capability (Re)Configuration

The recent literature related to the dynamic CBV, to cognitive and behavioral theory, and to knowledge management have started to detail how capabilities work (Teece, 2007). These works will improve the understanding of how firms can manage capabilities and reconfigure them using their dynamic capabilities. The capabilities analysis is conducted in at least three levels: operational, portfolio, and constellation level (Lavie, 2006). Some concepts useful for these three levels of analysis are described as follow:

The *operational level* evaluates the evolution of each capability and its fitness to the purpose of the capability, which, in turn, is defined by the perception about the environment. The capabilities are described as presenting a lifecycle induced by development by use, routines accumulation, and stabilization. Initially, the evolution is described by a simple knowledge and experience accumulation, frequently associated with individual capability of one person, and possibly no identifiable structure for the capability can be defined. With time, routines are defined and the 'know-how' is integrated into products and services and recognized in the organization. With the progress of structural complexity, a synergy between capabilities and resources, and with other capabilities, is needed (Figueiredo, 2004; Helfat & Peteraf, 2003; Pandza, Horsburgh, Gorton, & Polarjnar, 2003; Rush, Bessant, & Hobday, 2007).

The evolution of each capability described by the lifecycle is also as assisted by the specific and directed actions of dynamic capabilities. This cycle becomes conscious or pro-active inside the companies, with an increasing level of formality and manageability of the dynamic capability. Initially, the changes occur reactively. Progressively, bearing in mind the feedback from the market, the firm or enterprise learns to use the available information and reconfigure the capabilities, exploiting internal opportunities, and, at the higher level, it acts proactively, planning the capability reconfiguration (Pandza et al., 2003).

There are also different mechanisms of capability reconfiguration. Those mechanisms are in charge for promoting the evolution, as capability stabilization comprised by routines codification, standardization, integrating control and managerial practices and routines. If the capability's configuration is no longer able to yield adequate results, it can be replaced and a new capability can be developed internally or acquired from the environment, from an institution or a firm. Sometimes, this acquisition can be understood as a learning process with some adjustment inside the company (integrate the *capability portfolio*), or it may be achieved by alliance establishment, integrating a suitable firm or institution in the enterprise (integrate the *capability constellation*) (Lavie 2006; Sirmon, Hitt, & Ireland , 2007). The definition of an adequate reconfiguration mechanism is also an objective of decision making, enabled by the ability of the company or enterprise to identify the needed capability configuration and to decide how suitable the existing one is.

Concepts of Capability Fitness

The description of Lavie (2006) of the three levels of capability evaluation indicates that there is not just a capability existence or absence, but the idea of *fit* (technical or evolutionary). The operational *fitness* of a single capability in an isolated manner does not define the advantage for the enterprise or firms. What defines this advantage is the integration of capabilities in a concise structure that enables value adding (Hubbard et al., 2008). For this reason, analyses at portfolio and constellation level are also conducted.

The portfolio and constellation level analysis observes and collects data and interprets them in the aim to determine the attention and resources allocation in relevant capabilities. Inside the enterprises and firms, the resources are limited, sometimes even subject to competition. The conjoint of capabilities that comprise the portfolio (firm) or constellation (enterprise) of the capabilities presents a variety in the development level, and some capabilities will always be less developed than others. Therefore the trade-off analysis forms one of the objectives of the portfolio/constellation level analysis (Kazanjian & Rao, 1999; Lavie, 2006).

Several concepts of capability fitness are presented in the relevant literature (Barney, 1991; Capron & Mitchell, 2009; Helfat et al., 2007; Lavie, 2006; Metzenthin, 2005; Sanchez & Heene, 2010; Sirmon et al., 2007; Teece, 2007; Zott, 2003). The variety of fitness measurement concepts shows that capability analysis is a complex and multicriterial analysis/decision-making process. For the purpose of the model, the capability fitness concepts listed below were compiled in the following three macro concepts: (i) momentary performance; (ii) the future performance, considering stability; and (iii) the future performance, considering change. The concepts are presented and described in Figure 1.

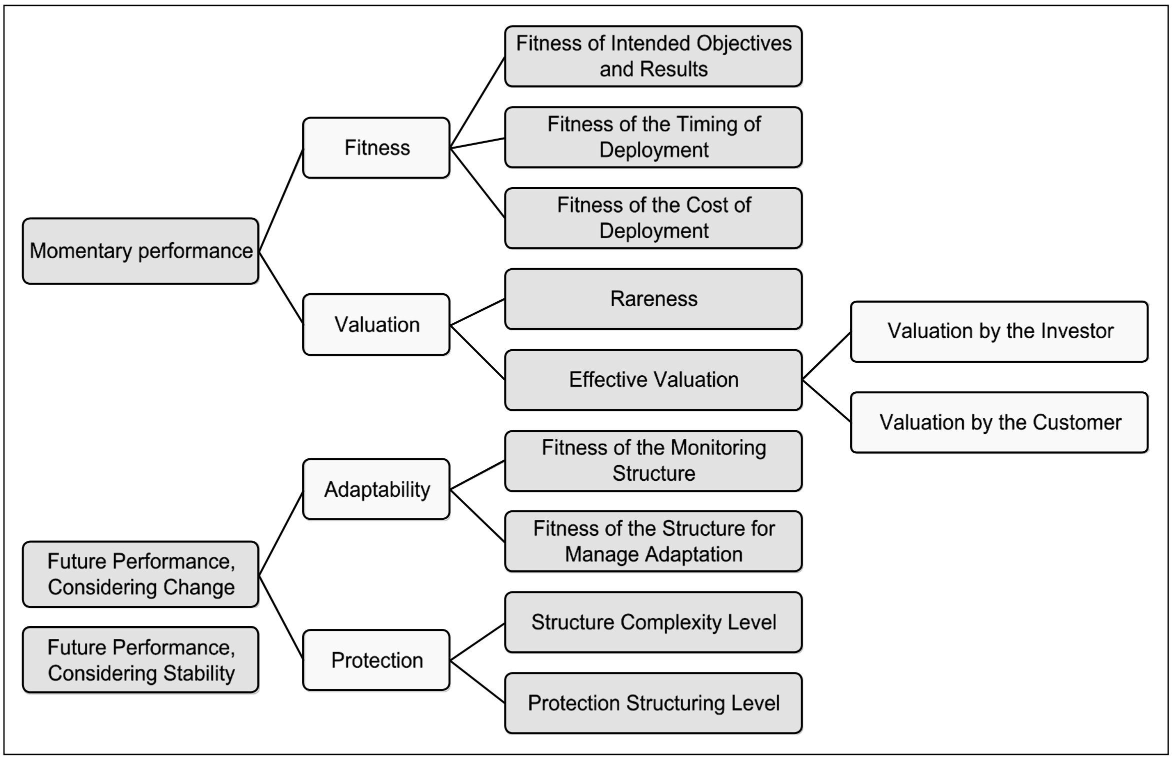


Figure 1. Capability Fitness concepts hierarchic tree.

The *momentary performance* construct is comprised of the dimensions fitness and *valuation*. The fitness dimension is divided into: (i) technical fitness, which includes the idea of closeness (Capron & Mitchell, 2009), operational gap (Metzenthin, 2005; Sirmon et al., 2007), external fit (Siggelkow, 2002), and capability strength (Capron & Mitchell, 2009; Helfat et al., 2007); (ii) fitness of the timing in the releasing of results; and (iii) fitness in the deployment cost (Zott, 2003). The valuation dimension is comprised of the Barney's (1991) rare (R) and valuable (V) concepts of the valuable, rare, inimitability and nonsubstitutability (VRIN) properties. The subdimension *rareness* represents the potential of valuation, and the valuation determines the effective valuation, as valued by costumer and by investor. The customer valuation embraces a concept based on capability-based management, an extension of the value chain approach (Hubbard et al., 2008). This evaluation is conducted by comparing the perceptions of the customers about the capability results to establish whether another approach is more valuable than the alternative one.

The second construct evaluates *future performance, considering stability*. Stability is developed with the progression and evolution of the routines to strengthen and stabilize the capability, as traditionally expressed in concepts such as that of capabilities maturity (Figueiredo, 2004; Rush et al., 2007), development phases, and lifecycles (Helfat & Peteraf, 2003). In this evolution, there is also a search for: (a) internal coherence, described by concepts such as organizational embeddedness (Lavie, 2006), internal fit (Siggelkow, 2002), and path dependency, and (b) supporting structures derived by routines' interdependencies (Lavie, 2006). This construct is measured by one scale derived from the traditional technology maturity measurement metrics. In the first stage, the ability is absent or conducted rarely and by external sources. The second stage has no planning and management structures, and the ability is obtained by individual capability, not an organizational capability. The progression of the capability covers the routines definition, followed by formalization, and lastly, control and management routines.

The construct *future performance, considering change* evaluates the ability to adapt if needed. It is comprised of the dimensions of: (i) adaptability, and (ii) protection against imitation. The *adaptability* dimension incorporates the subdimensions: (i) quality of the monitoring structure, and (ii) adaptation easiness. The first sub-dimension (quality of the monitoring structure) evaluates the structure to recognize the need of change, based in the limited rationality concept: the enterprise and the firm process information based on their limitations to visualize the variety of available capability solutions (Aldrich & Ruef, 2006; Nelson & Winter, 1982; Nooteboom, 2000; Lavie, 2006; Simon, 1945). This sub-dimension also represents the concept of *sensing* (Pavlou & El Sawy, 2004). The second sub-dimension (adaptation easiness) evaluates the ability of the structure to enable change, such as the existence and suitability of the knowledge about the state of the art, orientation to adjustment to the environment, reconfigurability, culture for the change, and evolution and easiness to learn (Pavlou & El Sawy, 2004).

The dimension *protection against imitation* evaluates the potential of the enterprise to maintain the advantage (if existent). It is related to the inimitability and nonsubstitutability (IN) of the VRIN properties (Barney, 2001). Its first sub-dimension is the complexity level that makes the capability hard to imitate and represents the ideas concerned with the concepts of codifiability, teachability, complexity, system dependence, product observability, routines and capability interdependence, and causal ambiguity (Barney, 2001; Eisenhardt & Martin, 2000; Lavie, 2006; Kazanjian & Rao, 1999; Rivkin, 2000; Sanchez & Heene, 2010; Sirmon et al., 2007; Zander & Kogut, 1995).

The causal ambiguity is a feature of organizational, dynamic, and managerial capabilities that is related to the capability's complexity and subjectivity and which make it difficult to be imitated (Eisenhardt & Martin, 2000; Kazanjian & Rao, 1999; Rivkin, 2000; Sanchez & Heene, 2010). The tangibility concept reflects the idea that the ease of imitation is defined (at least partially) by the kind of resources deployed by the capability. Capabilities comprised of processes and routines performed by equipment, presenting fully identifiable material flow are tangible, can be easily understood, described, and mapped and, consequently, easily imitated. Those capabilities that have knowledge as a key resource, however, are likely to present a higher level of the feature described as *causal ambiguity*. This indicates the absence of clarity in the relations of relevant intervenient factors and dependencies with the capabilities results (Barney, 2001; Eisenhardt & Martin, 2000; Lavie, 2006; Rivkin, 2000; Sirmon et al., 2007).

The concept of interdependency between routines is also considered. The sequences of some routines are able to be fully mapped, whereas other routines are more complex or dynamic. The ease with which a routine can be mapped also facilitates imitation; even the main resource is more intangible, such as knowledge, when the information flow is also defined by the information system.

The more complex and sophisticated the enterprise, the more complexities will be present in its capabilities or in the connection between the capabilities. The number of departments and of individuals, the physical distance between units, or the existence of several product families also define the complexity of the enterprise, posing difficulties in the understanding of the interdependencies among routines of the capabilities and among capabilities.

The second sub-dimension is the protection-structuring level. It includes the traditional discussion regarding the protection of technological capabilities, largely observed in the technological industries. It is comprised of the legal structures for protection, such as intellectual property and the copyrights law and its effectiveness, but also other mechanisms for information security (Cetindamar, Phaal, & Probert, 2010). For example, information security practices such as access control, formal contracts of confidentiality agreement contracts, and information segregation are some of the possible mechanisms.

The Organizational Capability-Based Performance Evaluation Model

This model supports the operationalization of the process of technology conversion by enabling its monitoring. The model was developed as a performance-evaluation model, presenting the structures of a multicriterial decision-aid system. In the portfolio/constellation combined analysis, it also incorporates a trade-off analysis. As a monitoring system, it contains metrics to evaluate the performance of the process and, simultaneously, guides the decision making.

The elements of this system are described by Chiesa and Frattini (2009) as a number of steps. First, the *unit of analysis* is the process of technology conversion, independent of whether its conduction is by a company or by a group of companies. Second, the *control object* is defined as the technological and organizational capabilities and the portfolio of these capabilities, for the reasons indicated by the theoretical basis used in this work. Third, the model's performance-evaluation system is identified as a feed-forward *type* with motivational *objective*. The motivational objective helps to guide the strategic alignment of the evolution and fitting process conducted by the reconfiguring process.

It should be noted that the model evaluates the business-model evolution. The capability and the capability-portfolio target configurations are established in the initial stage of the process by the use of tools such as the Capability Roadmap. These definitions are also reviewed and updated during the process, using the model. Such prior definitions, and the continuous updating, guide a motivational evaluation process that is adjusted with the evolutionary approach.

The model was developed to assist in the description of, and encourage debate about, the cyclic process of learning (Checkland, 2000; Pidd, 2010). The constructivist approach allows the incorporation of the users' perception in the decision process (Bouyssou, Marchant, Pirlot, Tsoukias, & Vincke, 2006). Specifically, the system has the following objectives: (a) to enable the description of the status of capability development in the enterprise; (b) to promote the debate about the evolution of the process of conversion of technologies in products, services, and processes and its early results; and (c) to decide in which capability areas to allocate efforts and attention to conduct the process, with the aim of creating adequate organizational conditions to facilitate good process performance.

Evaluation Metrics

Although the theory about organizational capabilities is not yet fully developed, especially regarding how to collect, measure, or analyze data and how to take decisions, the firms take decisions using subjective data obtained from analyzing the perceptions of the managers (Ackermann, 2011). For this reason, the performance evaluation system was developed using the quantification of human perception.

The system deals with three constructs for evaluation: (i) the momentary performance; (ii) the future performance, considering change; and (iii) the future performance, considering stability. These constructs collate the several capability fitness concepts available in the literature. The momentary and future performance (considering both change and stability) constructs capacitate the evaluation at the operational level. The conjoint of the scores representing the fitness of capabilities can then be grouped to enable the evaluation of the portfolio or constellation of the capabilities. Thereafter, the three levels of evaluation of Lavie (2006) are applied in the model.

Regarding performance dimensions of performance measurement systems (Chiesa & Frattini, 2009), the model is used to evaluate the following dimensions: (a) the quality dimension, related to the costumer expectation, to evaluate the value aggregation by adjusting to the customer and environmental needs, which are closely related to company survival; (b) the time dimension (in this context, related to the timing for resource deployment by the capability); and (c) the innovation or flexibility dimension, expressed by the learning level. This is an important aspect for nascent enterprises or for one in the learning process to create a new business model. In the high technology companies, researchers have voiced strategic concerns about: (a) product launch, main objective of the process of conversion of technology; and (b) future performance, related to adaptability to change, a common concern regarding dynamic capabilities. The first concern is related to the quality dimension and the second to the flexibility dimension.

The model also includes a time dimension by monitoring the scores over time. The construct "future performance, considering change" enables the system to promote the dynamic capability discussion, which is very relevant in the context of technological areas, in which frequent changes occur. The specific dynamic capabilities operate in particular organizational and technological capabilities in order to facilitate their evolution and reconfiguration in a faster, more efficient manner (Collis, 1994; Helfat & Peteraf, 2003; Teece et al., 1997; Winter, 2003; Zahra et al., 2006; Zollo & Winter, 2002).

The scales used in the model are presented in Table 1 and described in the following sections.

Table 1
Scales, Anchors, and Associated Values

Index	Anchors and associated value				
	A	B	C	D	E
Fitness of the intended objectives and results	6%: Organizational capability is not existent; results are expected because of existing resources	6%: Capability concept is defined, but is not developed	15%: Capability concept is refined and developed	33%: Capability is developed but results are still insufficient	100%: Capability is developed and its results are sufficient and suited to accomplish the objectives
Fitness of the timing of deployment	5%: Deployment is delayed	7%: Deployment is significantly anticipated	21%: Deployment is a bit early, but enterprise does not obtain advantage from this	64%: The enterprise is searching for advantage of the early deployment	100%: Deployment is in time
Fitness of the cost of deployment	6%: Deployment costs are considerably higher than the competitors' costs	12%: Costs are higher than the competitors' costs	25%: Costs are similar to those of the competitors	52%: Costs are lower than the competitors' costs	100%: Costs are much lower than the competitors' costs
Rareness	6%: The capability configuration is similar to the existing ones, and the results are overdue	14%: Configuration and results are similar to existing ones	14%: Configuration is distinguished, results are overdue	41%: The configuration is distinguished; results are similar to existing ones	100%: The capability configuration is distinguished and results are innovative
Valuation by the investor	3%: No valuation	11%: Very low potential of valuation	14%: Low potential of valuation	32%: Reasonable potential of valuation	100%: Valued
Valuation by the customer	6%: Added value is lower than competitors'	9%: Added value is slightly lower than competitors'	14%: Added value is similar to competitors'	64%: Added value is higher than the competitors'	100%: Added value is much higher than the competitors'
Fitness of the monitoring structure	5%: The environmental monitoring is considered needless	5%: Environmental need is unknown and information is not available	21%: A structure to react to environmental change is existent	37%: Information fonts is known	100%: The environment is systematically monitored

Index	Anchors and associated value				
	A	B	C	D	E
Fitness of the structure for manage adaptation	4%: The capability management structure is absent	10%: It is believed that the enterprise has sufficient knowledge to react and to adapt	18%: The results of capability are monitored	42%: The results are monitored and know-how as related to the capability is high, enabling adaptation	100%: The relevant factors of routines and processes of the capabilities are systematically monitored and related know-how is prominent
Structure Complexity level	5%: The capability is extremely tangible (easily mapped or map is available) and presents low complexity (the routines are not so interdependent)	7%: The capability presents tangibility (mapped easily or practices are available to everyone) and is low complexity (low sharing of activities and routines with other capabilities)	19%: The capability presents low level of tangibility: it is easily described, although main resources are information, not material. Routines are simple or common domain, but interconnected, conferring medium level of complexity	21%: The capability presents very low tangibility and its routines and processes presents complexity: are not typical and interconnected, although easily described	100%: Capability is intangible and highly complex: several departments/equips/units are involved; key activities, processes are not common domain; are based in information flow; are shared with other capabilities and the interdependencies are complex. The result depends on several other capabilities
Protection structuring level	5%: No protection structure	7%: The main resources or routines of the capability are protected by registering intellectual property but it is considered not fully respected	22%: The main resources or routines of the capability are protected by registering intellectual property, respected in all working regions, but without information security mechanisms	44%: The main resources or routines of the capability are protected by intellectual property and there are information security mechanisms	100%: The main resources or routines of the capability is protected by intellectual property and there are sophisticated information security mechanisms
Development level	4%: Initial–capability not existent, is conducted by external persons	10%: Individual capability–occurs rarely and depends on personal abilities to be conducted	28%: Repetitive–routines are existent with informal definitions	74%: Standardized–is comprised of routines with formal definitions of procedures and registry and responsibilities	100%: Managed–is comprised of standardized routines, with metrics and integrated control of projects of improvement

Evaluation Structure

As presented in Table 1, in the aim to conduct an evaluation of organizational learning and motivational performance, the model incorporates behaviorally anchored rating scales (BARS) metrics designed for the sub-dimensions of the constructs (Armstrong, 2009; Campbell & Cairns, 1994; Hawkins, Albaum, & Best, 1974; Jacobs, Kafry, & Zedeck, 1980). Those scales include capabilities evolution stages, and each metric combines the concepts of one sub-dimension described in the conceptual maps. Sub-dimensions presenting a complex structure, comprising more than one concept, are designed as Guttman-type scales, and sub-dimensions with simple concepts have semantically differential scales. The anchors are in the amount of 5 for each metric and are generic descriptions, applicable to all kind of capabilities. The higher anchor represents the fitness of the capability to the goal configuration. The comparing standard comprises the prior definition of goal configuration.

Table 1 presents numerical scales with ordinal-scaled anchors. The ordinal-scaled anchors were converted to numerical scale to compose the summary index. This conversion was obtained by the paired comparison of the anchors, followed by simplified eigenvalue generation by geometric method, based on the perception of the researcher and the opinion of specialists. These eigenvalues were scaled to relative values, so 100% is attributed to the anchor with the idea of maximum fitness (Budescu, Zwick, & Rapoport, 1986; Doumpos & Zopounidis, 2002; Edwards & Barron, 1994; Golany & Kress, 1993; Goodwin & Wright, 2010; Saaty & Hu, 1998; Yoon & Hwang, 1995).

Operational level combined capability fit indexes

The individual capabilities are evaluated by 11 metrics, enabling a complex and very informative evaluation, but it does not allow for comparing the several capabilities that the enterprise has. So, in order to combine the several 'fit' concepts in three operational-level, combined indexes (corresponding to the three constructs), combining structures and weighting vectors are defined.

The combining structure uses the technique for order preference by similarity to ideal solution (TOPSIS) method. This method was selected because of the adequacy its axioms presented to the context: (a) the absence of a compulsory item, enabling the compensatory combing method; (b) the existence of ideal maximum value for each scale; (c) the existence of different priorities between the criteria (sub-dimensions); and (d) the objective of ordering the portfolio's capabilities according to the ideal level of fit (Doumpos & Zopounidis, 2002; Edwards & Barron, 1994; Goodwin & Wright, 2010; Olson, 2004; Yoon & Hwang, 1995).

Regarding weighting vector, although a constructive approach for a decision method was intended, it was considered that asking the respondent to weight the metrics (sub-dimensions of constructs) would not be practical in the proposed context of analysis. The system presents a considerable number of criteria, and the number of capabilities for evaluation in an enterprise is estimated to be at least 10. After considering some options that do not ask the respondent's opinion, that is, the rank order centroid (ROC) and the specialist-based definition of the weighing vector, the latter was selected, as ROC conducts numerical conversion without theoretical bases. Furthermore, within the specialist-based methods, paired comparison with the geometric-mean method was preferred over the subjectivity of the swing-weights method, as the paired comparison, followed by the geometric mean, represents a simplified application and is largely used in the Analytic Hierarchy Process (AHP) method (Budescu et al., 1986; Doumpos & Zopounidis, 2002; Edwards & Barron, 1994; Golany & Kress, 1993; Goodwin & Wright, 2010; Saaty & Hu, 1998; Yoon & Hwang, 1995). The resultant weights are presented in Figure 2.

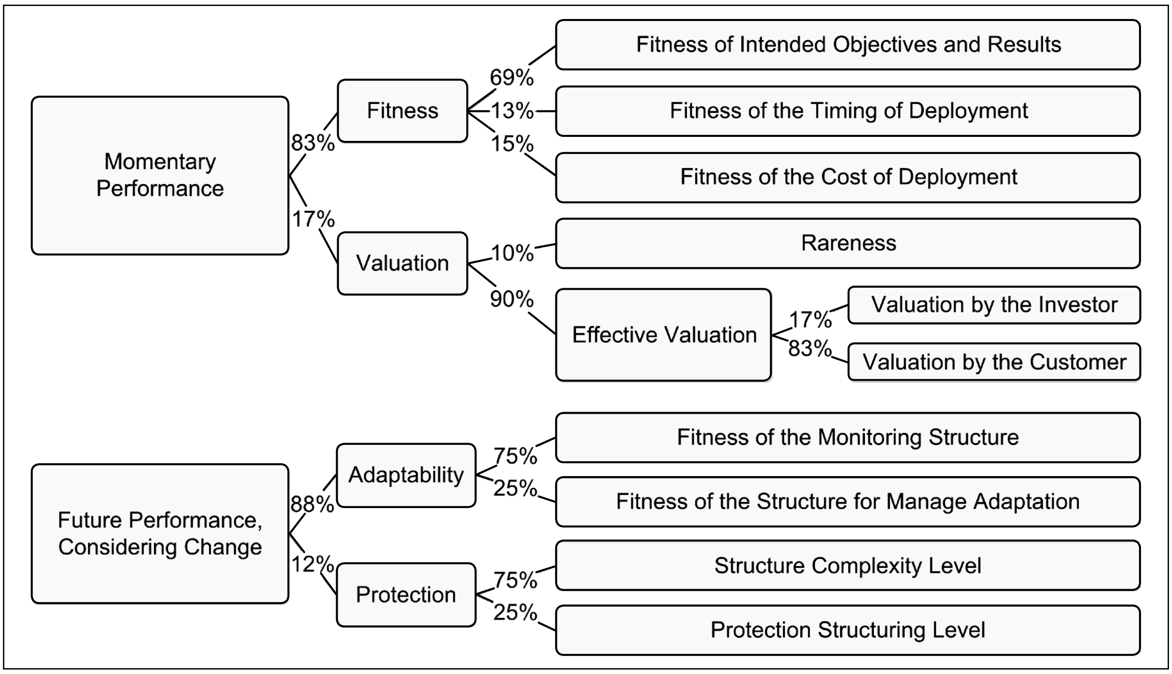


Figure 2. Hierarchic tree with weighting values for operational level index calculation.

With this combining structure, the model obtains three operational level indexes per organizational capability in the enterprise. The operational level indexes enable the analysis of one capability. However, the enterprises rarely have resources to develop and fit all capabilities. The number of organizational capabilities does not allow easy analysis, and capabilities development needs resource, time, and attention in the allocation process and frequently involves some kind of trade-off procedure. Hence, the combining of the operational level indexes with the portfolio/constellation level was also applied as a way to estimate the capability portfolio/constellation efficiency.

The capability portfolio/constellation evaluation

The capability portfolio- or constellation-level evaluation is based on the weighted additive model. The operational level indexes are grouped in the portfolio level without distinction between which company contributes the capability to the enterprise. This grouping method was selected for the structure because of the following properties: (a) the trade-off idea resulting from the fact that the enterprise can compensate (to some extent) for the low fitness of one capability by a better fit in another; and (b) the ability to consider the existence of a possible relative importance of different capabilities to the context of the enterprise.

The weighting vector W was obtained by ROC. This method was selected because of its adequacy to meet the requirements of the evaluation because of the following features: (a) flexibility to adapt to the different number of capabilities in different enterprises; (b) ability to obtain different weights by considering the perceived priority in the enterprise; (c) simplicity that enables application without inserting more complexity into the evaluation system; and (d) no necessity for numerical ability from the operators (Edwards & Barron, 1994; Goodwin & Wright, 2010).

Reporting structure

The resultant indexes are organized by graphical representations, in the reporting structure because of: (a) the induction of an adequate interpretation of the low precision indexes; (b) the easy global and generic analysis; and (c) the method developed is neither as sensible nor robust as a detailed quantitative comparison because of the nature of the object of the analysis and the perception-based analysis. The graphical approaches are composed of: (a) a bidimensional performance matrix, presenting two criteria (dimensions) disposed in a plane, which enables the classification of the analysis unit; and (b) a dashboard comprised of a variety of graphical methods that enables the representation of adjustment percentage (Armstrong, 2009; Bouyssou et al., 2006).

Case Study

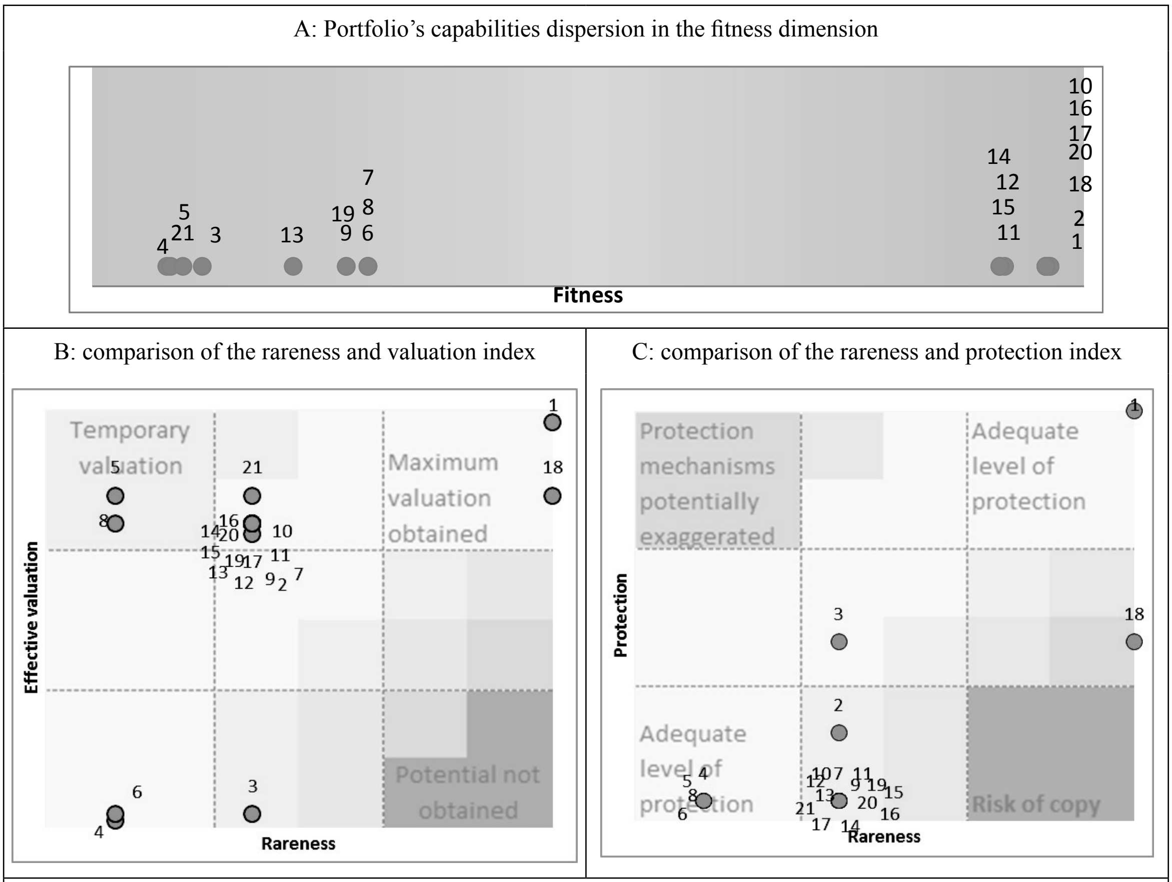
The model was applied to a case study conducted on an enterprise sited in Brazil. The enterprise has five components (four companies and one academic laboratory), having 21 capabilities. It started with Firm A, an academic spin-off company created with the aim of converting the technology knowledge and intellectual property resulting from an academic research study. This company is installed in a university technological incubator of the federal university in which the original academic research was conducted. The two researchers who originated the intellectual property are the founders and the main owners of Firm A. The interaction with the academic laboratory in which the research was originally conducted was considered important and was thus included as one of the components of the enterprise. The enterprise has as its objective the conversion and commercialization of the technology used to produce commercial products and services. At the time of the analysis, the management considered the product fully developed, but the service development was still in progress. They considered the business model to be roughly defined in terms of the enterprise's components and its roles.

The evaluation was conducted by the interaction of the researcher with the business manager of Firm A, the main company in the enterprise, using the anchors presented in Table 1. The answers were converted in a numerical matrix by the value conversion, also depicted in Table 1. Thereafter, the values in the numerical matrix were used to obtain the indexes for capabilities in the operational level (matrix O). The values were combined by the TOPSIS method to operational level indexes, measuring the Euclidian distance of the value attributed to each scale to the optimal coordinate, that is, when all dimensions are fitted in the maximum level (100%). The minimum coordinate, as composed by all dimensions, is designated as zero (0). The scales are grouped, using the weighting vector, preceded by vector normalization. Considering the compensatory nature of these indexes, each index has an indifference line, in which the same value of different performance O_{ih} is possible with distinct performance in different sub-dimensions.

Results-Capabilities Portfolio Fitness Dispersion

The conjoint of results of the operational level evaluation for Enterprise A is presented graphically. The bidimensional graphics present the capability dispersion with attention zones that allow several pertinent discussions related to typical technology, value chain, and process management themes. Some examples are: (a) value adding on potentially valuable capabilities, which is indicated by the rareness index; (b) adequacy of the protection level of valuable (potential and effective) capabilities; and (c) trade-off between stabilization of the capability by formalization and flexibility, indicated by fitness in future performance in case of a change in construct. This analysis is labeled portfolio/constellation level analysis because it presents the dispersion of the capabilities of the enterprise, without distinction of the integrant that dominates them.

One example is presented in Figure 3. The comparison of the rareness index with valuation (Figure 3-B) and protection (Figure 3-C) permits some traditional debates of the technology management area. The diagrams present regions of attention and adequacy. Figure 3-B illustrates that the majority of capabilities are located in the adequacy regions. However, two capabilities are located in the temporary valuation area. The enterprise management must be aware of this and be prepared to improve them or work without the value of these capabilities.



1. ability to develop technology
2. ability to manufacture the robot
3. ability to assure quality (accuracy, precision, calibration)
4. ability to interact with the customer
5. ability to execute services
6. ability for internal management
7. ability to obtain investments
8. ability to manage alliances
9. ability to conduct training
10. ability to manage quality system
11. ability to define target market and applications to the technology
12. ability to allocate resources and attention inside the enterprise
13. ability to conduct changes in the industrial and market environment: technological development of suppliers and costumers
14. ability to develop process
15. ability to create, integrate, and reconfigure organizational resources and competencies to develop organizational capability
16. ability to integrate and align human resources to the enterprises objectives
17. ability to coordinate internal and external resources to enable the enterprises adding value objectives
18. ability of the enterprise to perceive, assimilate and apply new knowledge
19. ability to control costs
20. ability to define if the needed resources must be acquired or developed internally, and, if acquired, from who?
21. ability to manage the interfaces to define adequate control mechanisms to the service execution or manufacturing process

Figure 3. Main results for enterprise' portfolio's capabilities dispersion.

Another two capabilities are located in the maximum level of the two dimensions, which means that the capabilities are distinctive, with maximum use of this potential of valuation. Investment in the protection of these two capabilities is recommended. The analysis of the protection level is enabled by the figure located on the side (C). It can be observed that one presents a high level of protection but the other does not. Also noteworthy is that the majority of the capabilities are located in the region inferior to adequacy, indicating that the enterprise does not invest in protection mechanisms. The two figures furthermore allow a simplified (or indirect) three dimensional analysis of the portfolio/constellation. Each capability must also be analyzed in an isolated manner because some specific characteristics of the capability may ensure protection against copy by inimitability, thus requiring less effort to be protected.

Portfolio Level Indexes

The dispersion graphic with the fitness dimension (Figure 3-A) shows that the enterprise presents several capabilities fitted in higher levels, whereas others are presented in very low levels. This was considered consistent with the enterprise in the end of the product conversion phase, almost commercializing the product. This graphic is very informative in the evaluation of portfolio and constellation level. Nevertheless, graphical analysis does not enable monitoring along time. The portfolio level indexes are more desirable for this purpose.

The obtained portfolio level indexes are presented in Figure 4:

	Momentary performance	Rareness	Valuation	Fitness	Future performance, considering change	Adaptability	Monitoring structure quality	Adaptation easiness	Protection against imitation	Complexity level	Protection structure	Future performance, considering stability
Vector P	52.71	44.75	66.21	55.89	15.00	24.24	33.27	53.47	5.50	14.03	24.21	35.49

Figure 4. Portfolio level indexes obtained for Enterprise A.

Considering the target value previously defined, it is obvious that the enterprise can be considered adequate in the momentary performance, valuation, and fitness dimensions, considering the stage of development. Nevertheless, the dimensions' adaptability, and protection against imitation, is not developed in the desired level, thus raising a question about future performance, if considering the changing scenario. Clearly, the enterprise does not have a very well-developed culture for capability or resource protection. Otherwise, the future performance, considering stability is more developed, although not yet adjusted to the ideal level.

The main integrant of the enterprise was, at the time the analysis was conducted, just starting to implement a formal quality system, by imposition of the requirements of a chosen market. In the technological area, it is usually not suitable to make greater investment in stabilization that can impact on difficulties in the future, to change the structure because of the frequent change in environment, occasioning some debate.

Conclusions and Future Works

The selected method enables a systemic analysis of a technology conversion enterprise. The method comprises an evaluation structure that produces the elaboration of a report with graphical representation of results which allows qualitative analysis that guides several relevant discussions on the technology management and capability-based management approach.

In this paper, just a single case study was presented, a research design that provided deeper understanding. Nevertheless, a more broad application, in the form of a multi-case study, is proposed as a future work, with the aim of permitting generalization. This proposed study will assist in analyzing the technology-based companies and the environmental influencing factors, thus facilitating conclusions and generalizations.

Modern innovation structures are not restricted to just one company but consist of an innovation chain composed of several companies and institutions. The selected method enabled a systemic analysis, considering also complex enterprise configurations, composed of more than one company. For this situation, however, evaluation of another construct is needed: the balance of capabilities inside the enterprise, considering concepts such as, for example, resource and capabilities complementarity, existence of idiosyncratic capabilities, and the need for stability in some alliances.

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