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Engenharia, Tecnologia e Gestão
INSTITUTO FEDERAL Paraná

# THE CAPABILITY-BASED VIEW OF R&D AND MANUFACTURING INTERFACE IN DYNAMIC ENVIRONMENTS

Tomoe Daniela Hamanaka Gusberti[1]
Carla Simone Ruppenthal Neumann[2]

**Abstract:** Actual technological development does not occur solely when new technological products become available. It just effectively occurs by the application of value-adding processes. These processes can only occur after manufacturing processes become viable. Therefore, companies must remain agile during product development, manufacturing, and supply and value-adding processes. The needs of the extended company must be considered. This paper presents a theoretical discussion of the utilization of CBV literature as the basis for the configuration of the extended company. The qualitative, multidisciplinary, and theoretical research conducted for this paper was based on the inductive method. Manufacturing Management, Research and Development, Business Model, and Capability-Based View knowledge domains were evaluated to discover their potential contributions to design approach elements. The Capability-Based View is proposed as an approach that can be employed in the planning process for new enterprises. It can also be included in performance measurement processes. This approach enables monitoring and decision making during the evolution of Business Models by the use of organizational capabilities as the change-tolerant, performance measurement monitoring unit. This work contributes to the current literature by presenting an analysis of several knowledge domains based on the design approach. It also provides a discussion of methods of unification and suggests further research that should be conducted to enable the design of an adequate Business Model for dynamic environments.

**Keywords**: Capability Based View, Business Model, Manufacturing Management, R&D, New Product Development.

[1] Dr. Eng, UFRGS' Science and Technology Park & Office of Technological Development - Universidade Federal do Rio Grande do Sul – UFRGS. Praça Argentina S/N Chateau – Predio 11.102 CEP 90.040-020 – Porto Alegre/RS – Brazil. Tel: +55 (51) 3308-3800 Fax: +55 (51) 3308-4237 E-mail: tomoe.gusberti@ufrgs.br
[2] Dr. Eng., Administration School - Universidade Federal do Rio Grande do Sul – UFRGS. Rua Washington Luiz, 855, Sala 421 - Centro Histórico. CEP: 90010-460. Porto Alegre/ RS :: Fone: +55 (51) 3308-3724 :: Fax: +55 (51) 3308-3991 E-mail: csrneumann@ea.ufrgs.br.

## 1 INTRODUCTION

The environment of the majority of industries is called dynamic, even for the globalization process and international competition, or by the incorporation of new technologies. Scientific and political discussions had concerned about technological development of nations, one of dimensions of these dynamicity. But it is reminded that the actual technological development does not occur because the incorporation of new technologies in new components or products. It also occurs owing to effective application of value-adding processes. These processes can only occur when manufacturing processes become viable, and viability occurs more easily when the entire supply chain has been technologically developed (LALL, 1992).

Several knowledge domains have discussed this theme by several different perspectives. The majority of technological industry environments are dynamic. New technologies are frequently introduced and new products are constantly incorporated into the manufacturing processes. Often, these new products require the development of radically new manufacturing processes and structures that differ considerably from those that previously existed (CHESBROUGH; ROSENBLOOM, 2002; LEONARD-BARTON, 1992). The Research and Development (R&D), the generator of new technologies and new products, delivers inputs for Manufacturing Management (MM) actions, and R&D also demands changes from manufacturing processes. Some of these changes can be very significant. Contemporary practices in New Product Development (NPD) and R&D knowledge areas attempt to accomplish these changes by their access to and development of process technologies and their discussions of concurrent engineering, integrated, multidisciplinary and cross-functional approaches to NPD and R&D (CLARK; FUJIMOTO, 1991).

The ideas that companies have to remain agile during the development of products and manufacturing, supply, and value-adding processes are present in the MM, specially by the agile manufacturing model (GOLDMAN; NAGEL; PREISS, 1995; SHARIFI et al., 2001). In this holistic view, companies may not necessarily find internal methods that enable adequate manufacturing processes. At times, changes in the methods of conduct for organizational interactions with the supply chain and the environment may be needed. Hence, the needs of the extended company must be discussed. Companies' abilities to manage and reconfigure themselves can be described as strategic flexibility.

The development of value-adding chains and Business Models (BM) are important planning goals for all companies. The both concepts comprises the idea of identification, creation and connection of the all processes and interaction among companies that add value to the product and service and enable their delivery and usefulness and desirability perception of the customer.

However, innovation in this value chain can occur in different degrees in different companies.

To help the majority of industries cope with the dynamicity of the current environment, new paradigms are needed that link R&D and MM and consider the extended company. The agile manufacturing cope with concurrent engineering principles and practices as agility providers (BROWN; BESSANT, 2003; ZHANG; HARIFI, 2000). Contemporary references of last 15 years consider not only the company and its internal structure but also the supply and value chain. The agile manufacturing considers concepts such as virtual enterprise and partnership (GUNASEKARAN; YUSUF, 2002; ZHANG, 2011). For decades, prior studies on R&D have presented discussions about amplified requirements for product development managements: customer focus, concurrent engineering, integrated product development, and methods for the integration of manufacturing processes with product development processes. Contemporary discussions include other stakeholders and principles as open innovators and co-developers (CHESBROUGH; ROSENBLOOM, 2002; LICHTENTHALER; LICHTENTHALER, 2009).

New paradigms that address these requirements can be described as holistic views. Some authors acknowledge the relevance of the CBV in their explanations of the role of R&D as a support system for companies as they adjust organizational structures to environmental needs. This includes the adoption of a proactive view of flexibility (DANNEELS, 2002; EISENHARDT; MARTIN, 2000; LEONARD-BARTON, 1992). When some MM authors present strategy-related discussions as agile manufacturing, they employ the organizational capability concept. They describe agility as a capability that can be obtained by the implementation of tools and practices that include environmental factors (SHARIFI; ZHANG, 1999; ZHANG, 2011). Hence, the CBV is a tendency found in R&D and MM literature.

The multidisciplinarity and the interdisciplinarity are referred by the literature as a needed characteristic for new disciplines to enable comprehension of complex phenomenas. But to consolidate this interdisciplinarity and to evoluve to a more useful and complete discipline, the knowledge domains must not just confronted one discipline to another, but barriers must be  breaked to create new practices and methods (HALL; TIROPANIS, 2012; KLEIN, 2010).Hence, this paper contributes to the evolution of the interdisciplinarity of these (until now) divergent knowledge domains, comparing and discussing them regarding interface in dynamic environments, and their complementarity based in the systems design perspective.

## 2. METHODOLOGICAL CONSIDERATIONS

This paper presents qualitative, multidisciplinary, and theoretical research based on the inductive method. Comprises a theoretical discussion of (a) the usefulness of the knowledge domains as resource for the configuration of the extended company in dynamic environments; and (b) methods for the unification. The analysis was conducted using concepts from the systems engineering and design approach. A progressive analysis is presented based on the conception that knowledge domains evolve in response to demands for practical applications. The evolution of these domains is based on the integration of all components of the system design process. The knowledge domains (i.e. MM, R&D, BM, and CBV) are evaluated for their potential contributions to elements of the design approach (e.g. divergent thinking phase, convergent thinking phase, descriptive knowledge, solution concepts, generative mechanism, and prescriptive knowledge).

## 3. KNOWLEDGE DOMAIN ANALYSIS

Companies compete in globalized ways, have more competitors, and customers are more demanding. To survive, they must have quality, flexibility, and agility, not just solely to offer and deliver products or services, but also in how to act in the market and how to take advantage of quick response enabler elements such as alliances and information sharing in the supply chain. The company and its development and survival are complex phenomena and several knowledge domains comply about these requirements, by slightly different focus. In this research four main knowledge domains were evaluated for multidisciplinary study: (i) Manufacturing management; (ii) Research and development; (iii) Business Model and (iv) Capabiltiy Based View. Although some mentions of one discipline about another is discretely observed, they are separated knowledge domains, with clearly different origins. There are even mentions about the need of a more clear connection between manufacturing and research and development, for example.

**Manufacturing Management (MM)** is a discipline worried about how companies can plan its organizational designs to deliver products and services in an effective and efficient way. Several specific worries emerges in this context, comprising quality, flexibility, manufacturing process design, agility, among others (GOMES; YASIN; LISBOA, 2011; SLACK, 1987; STEVENSON; SPRING, 2007)

| **Manufacturing Management** |
|---|
| • new manufacturing technologies, materials, products; agility and adaptability; reduction of waste, increase in efficiency and productivity, and increase human involvement (ELMARAGHY; WIENDAHL, 2009); organizational designs (APRILE; GARAVELLI; GIANNOCCARO, 2005; BEACH et al., 2000; ELMARAGHY, 2006; SAWHNEY, 2006; SLACK, 1987; STEVENSON; SPRING, 2007); technologies related to enable communication and monitoring (GUNASEKARAN; YUSUF, 2002); how can companies configure themselves to deliver necessary agility (BROWN; BESSANT, 2003). |
| **R&D= technology management, innovation management; +** |
| • Engineering cycle process; Product development techniques, methods, models and tools. (CLARK; FUJIMOTO, 1991; COOPER; EDGETT; KLEINSCHMIDT, 2001; COOPER, 2008); Operational research for optimization purposes; Best practices; Corporate renewal, business evolution, (re)configuration of internal organizational capabilities, the entire supply chain (CHESBROUGH; ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; MORRIS; SCHINDEHUTTE; ALLEN, 2005). |
| **Business model engineering** |
| • Representation of the ways that a company hopes to operate; how to capture value from technology, other resources, and opportunities;; governance, organizational, and market structure; ways to relate to the environment; decision variables (AMIT; ZOTT, 2001; CHESBROUGH; ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; MAGRETTA, 2002; MORRIS; SCHINDEHUTTE; ALLEN, 2005; SILVERMAN, 1997; TEECE, 2010); learning- or discovery-driven approaches (CHESBROUGH; ROSENBLOOM, 2002; MAGRETTA, 2002; MCGRATH; MACMILLAN, 2010; MORRIS; SCHINDEHUTTE; ALLEN, 2005). |
| |
| • Organizational capabilities (EISENHARDT; MARTIN, 2000; TEECE, 1996), Routines (NELSON; WINTER, 2009), Dynamic capabilities for organizational growth and evolution (TEECE, 1996); Capabilities' properties and evaluation concepts, p. ex. Barney's (1991) VRIN properties, Fit (CAPRON; MITCHELL, 2009; HELFAT; FINKELSTEIN; MITCHELL, 2007; LAVIE, 2006), capability portfolio or constelation (HUBBARD et al., 2008; LAVIE, 2006), Capabilities maturity (RUSH; BESSANT; HOBDAY, 2007), development phases, lifecycles (HELFAT; PETERAF, 2003); Proactive planning based on the CBV (HUBBARD et al., 2008; SANCHEZ, 2004). |

**Figure 1 : main worries and concepts of the knowledge domains**

The topic of **Research & Development** (R&D) has been the focus of several literature streams. Although other literature streams is possible, this paper analyzed the following traditional and more practical streams: (a) technology management, a stream that remains closed to innovation management (e.g. Nārāyaṇan and O'Connor, 2010; Tidd and Bessant, 2011); (b) systems engineering, a more practical stream (e.g. Clark & Fujimoto, 1991; Hitchins, 2007; Stevens, 1998); and (c) product development management, a sub-stream that includes several practices employed in the systems engineering stream. This sub-stream is applied mainly in the management of new product development processes (e.g. Clark and Fujimoto 1991; Cooper 2008). In the past, these literature streams were divergent. Currently, they have become similar, to a certain extent. In this paper, these streams of research are referred to as the R&D-related knowledge domain.

The **Business Model** (BM) is a representation of the ways that a company hopes to operate. The BM summarizes the ideas and methods used to create value through exploitation of business opportunities. The BM is managed, planned, in the process also called BM Engineering, and developed by the elaboration of assumptions and the examination of these assumptions at successive milestones (AMIT; ZOTT, 2001; CHESBROUGH; ROSENBLOOM, 2002; MAGRETTA, 2002; MCGRATH; MACMILLAN, 2010; MORRIS; SCHINDEHUTTE; ALLEN, 2005; TEECE, 2010).

The **Capability-Based View** (CBV) is a theoretical domain originated from the strategic management and relies on organizational capabilities as a primary concept. Being strongly related to the value network concept, capabilities can be considered ways that add value to final customers that transcend the limits of a company. The central theme of the CBV is the dynamic capabilities that can enable organizational growth and evolution (EISENHARDT; MARTIN, 2000; TEECE, 1996; WINTER, 2003; ZAHRA; SAPIENZA; DAVIDSSON, 2006; ZOLLO; WINTER, 2002). The Figure 1 presents the main worries and concepts of the knowledge domains.

Following, the knowledge domains are analyzed according to decision or study object in the organization, their connections, and the contribution to the knowledge evolution (design) process.

### 3.1 Consideration about the decision or study object

The knowledge domains decision or study object is summarized in the Figure 2. The systems engineering perspective (of **R&D domain**) has been the subject of operational and practical concerns since its origin. The systems engineering perspective has evolved into managerial and strategic approaches over the last few decades. To address the complexity of systems, this perspective adopts some concepts from alternative knowledge domains. For example, system complexities can evolve from social and psychological features of socially constructed systems, adopting alternative basic sciences, such as social sciences and management sciences (BRILL, 1998; CARLOCK; FENTON, 2001; HITCHINS, 2007; OSMUNDSON et al., 2004; ROUSE, 2005; SHEARD; MOSTASHARI, 2008).

| | |
|---|---|
| R&D | systems engineering presents several efforts to address the complexity of systems (CARLOCK; FENTON, 2001; GROSSMANN; WESTERBERG, 2000; HITCHINS, 2007; OSMUNDSON et al., 2004; STEVENS, 1998).<br>Corporate renewal, business evolution, (re)configuration of internal organizational capabilities, the entire supply chain (CHESBROUGH; ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; MORRIS; SCHINDEHUTTE; ALLEN, 2005). |
| MM | The evolution described by the succession of the following managerial eras: Mass production systems; Flexible production; agile manufacturing systems (DUGUAY; LANDRY; PASIN, 1997; MEHRABI; ULSOY, 2000). |
| BM | learning- or discovery-driven approaches (CHESBROUGH; ROSENBLOOM, 2002; MAGRETTA, 2002; MCGRATH; MACMILLAN, 2010; MORRIS; SCHINDEHUTTE; ALLEN, 2005) guiding the decisions conserning how to capture value from technology, other resources, and opportunities (AMIT; ZOTT, 2001; CHESBROUGH; |

| | |
|---|---|
| | ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; GLISSMAN; SANZ, 2009; MAGRETTA, 2002; MORRIS; SCHINDEHUTTE; ALLEN, 2005; SILVERMAN, 1997; TEECE, 2010). |
| CBV | A evolution from RBV, focusing in how companies obtain advantage by presenting distinguished resourcs. And describes how companies and industries growth and evolve (EISENHARDT; MARTIN, 2000; NELSON; WINTER, 2009; TEECE, 1996) |

**Figure 2: knowledge domains' decision or study objects and their evolution in complexity**

New approaches in technology management and Product development process management literature are worried about corporate renewal and business evolution, not just by generating and delivering new products or services, but by (re)configuration of internal organizational capabilities and even the entire supply chain (CHESBROUGH; ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; MORRIS; SCHINDEHUTTE; ALLEN, 2005).

The agile manufacturing model (**MM)** encompasses the company, its internal structure, and the supply and value chains. It is based on concepts such as virtual enterprise and partnership, with volatility of the organizational structures constructing links (inter-firm cooperation) to enable a transient virtual enterprises, and dissolving them to bring competitiveness when new contexts emerges (BROWN; BESSANT, 2003; GOLDMAN; NAGEL; PREISS, 1995; GUNASEKARAN; YUSUF, 2002; JU; ZHANG; WANG, 2011). However, the adoption of enablers does not guarantee that a company will become agile. Many unanswered questions exist that future research should explore: (a) how can companies identify the particular configurations necessary for specific sectors, products, or markets; and (b) how can companies configure themselves to deliver necessary agility (BROWN; BESSANT, 2003).

The **CBV** comprises an evolution from resource based view (RBV) that aimed to describe how companies obtain advantage by presenting distinguished resource. CBV describes how companies and industries growth and evolve (EISENHARDT; MARTIN, 2000; NELSON; WINTER, 2009; TEECE, 1996), and some new approaches intends to define how to use these theoretical background to take decisions (HUBBARD et al., 2008; SANCHEZ, 2004). Owing to the limited rationality of companies, some concerns exist with respect to the minimization of operational and cognitive gaps during the planning process. The environment-understanding perspective results from efforts of organizational capabilities to collect and process data and information. If a company does not possess suitable capabilities to understand environmental conditions, the potential fit may not be effective (LAVIE, 2006; NOOTEBOOM, 2006; SIRMON; HITT; IRELAND, 2007). This view complements the agile manufacturing literature stream described previously.

Hence, it is possible to say that one commonality between the MM and R&D knowledge domains is the recent search for a more holistic view, as the historical work specialization culture lead to a management's shift towards specific functional objects (e.g., product development, control of the manufacturing process, etc.). This shift has resulted in the loss of the holistic or systemic view that values the integration of all functions, resulting in a lack between the domains. The BM and CBV present potentiality to connect them as practical and theoretical basis for holistic and extended company view, as indicated in the following topic.

### 3.2 Knowledge domains connection map

Some emergent connection were mapped as presented in the Figure 3.

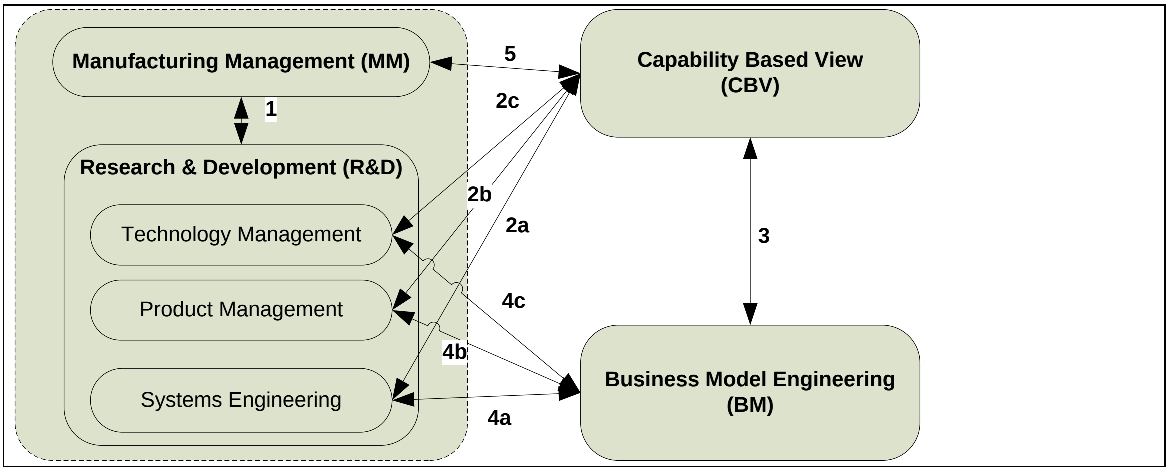


**Figure 3: Map of analyzed knowledge domains and evidences of connection**

The connections illustrated in the map are clearly emergent, because few publications that mention them.

The more clear **connection (1)** is between MM and R&D knowledge domains. Inspired in quality management practice, one of the MM research stream influenced product development and R&D literature, presenting best practice approach for some time (VOSS, 2005). The best practices approach in academic research and discussions originated with the search for understanding of the management models of some referenced companies, specifically TQM philosophy. In a more recent view, authors suggest the CBV as a promising knowledge domain in dynamic environments by offering not just a theoretical but also a complimentary approach (BURGELMAN; CHRISTENSEN; WHEELWRIGHT, 2008; CETINDAMAR; PHAAL; PROBERT, 2009, 2010). There are at first glance at least two conflicting knowledge domains: The so practice oriented Business Model domain and the theoretical CBV. The CBV is essentially a theoretical domain. At this time, its operationalization has not been well defined. Although by definition the organizational and dynamic capabilities are able to explain how company and industries evolves, just few authors discusses organizational capabilities as result from proactive planning based on the CBV (HUBBARD et al., 2008; METZENTHIN; PROFF, 2007; SANCHEZ, 2004).

The business model engineering is a new, emerging and trendy issue. For this reason, is yet a not so consolidated as knowledge domain, although very demanded as consulting or best seller business books issues. Some also can argue that as no theoretically funded knowledge domain, they use several other knowledge domain concepts. Although other configurationally elements are possible, the literature suggests that organizational capabilities can be useful for business model engineering (**connection 4)** within the context of the dynamic environment (FLEISCHER; HERM; UDE, 2007).

Capability-Based Planning (CBP) acts as **connection 2a**, a method adopted from the systems engineering knowledge domain, is a practice that explicitly applies the CBV. The CBP possesses some similarities with several product development process models. The CBP approach consists of cycles of deployment and refinement. It extends Requisite Management (or Requisite Engineering - RE). Rather than converting and deploying market needs into requisites and specifications, the CBP begins with capabilities definition. The deployment of capabilities to needs, requisites, and specifications make up the requirements volatility concept and enable change-tolerant planning because capabilities are considered to be the constant during this evolution (DAVIS; SHAVER; BECK, 2008; RAVICHANDAR et al., 2008; TAGAREV, 2006).

The Technology management literature (of R&D domain), was originated within economic literature, present also some worries about company level. Although macro environment focused objectives are also observed, the main discussions address ways to structure the product development process and to transform product development at the corporate level. In recent research, scholars have expressed concerns about corporate renewal, business evolution, (re)configuration of internal organizational capabilities, the entire supply chain, BM development, and the technological conversion of products and processes that, in the customer's view, add value (CHESBROUGH; ROSENBLOOM, 2002; DOGANOVA; EYQUEM-RENAULT, 2009; MORRIS; SCHINDEHUTTE; ALLEN, 2005). This shows the **connection 3c**. To address these concerns, researchers have suggested the use the other economic knowledge domain, the CBV (**conection 2c**). The CBV-related concepts was pointed as useful during firm-level and managerial discussions (CLARYSSE; MOSEY; LAMBRECHT, 2009; NĀRĀYAṆAN; O'CONNOR, 2010).

## 3.3 Considering the design process for knowledge evolution

Applied and engineering sciences conceives the design approach as it as a method that can bring research closer to practice (DENYER; TRANSFIELD; VAN AKEN, 2008; VAN AKEN; ROMME, 2009). In this topic, the knowledge domains were evaluated firstly regarding their knowledge component types, knowledge usage phases. The **Erro! Fonte de referência não encontrada.Erro! Fonte de referência não encontrada.** presents these main components and their relationship to the design process as understood in this work.

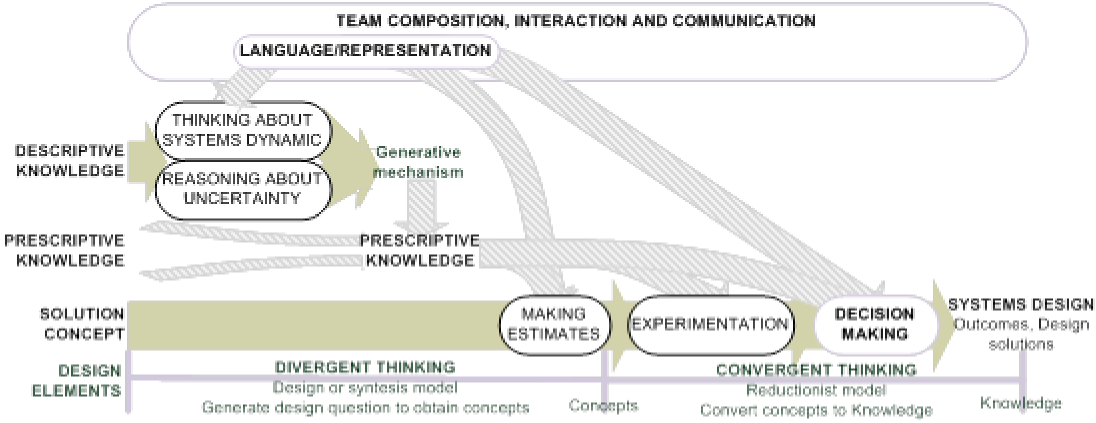


**Figure 4: Components of the system design process**

All knowledge domains comprises four types of knowledge (descriptive knowledge, generative mechanisms, solution concepts, and prescriptive knowledge). In the design or systems engineering process, these knowledge types are used in the divergent, and convergent phase. To enable the conduction of divergent and convergent phases, a specific language or representation codes are existent (DYM et al., 2005; VAN AKEN; ROMME, 2009). In this context, the systems to be described are named manufacturing process, product, product development process, and BM

### 3.3.1 Knowledge component types

Knowledge classes involved in the system design process include (a) descriptive knowledge, (b) solution concepts, and (c) prescriptive knowledge. Figure 5 shows associations of knowledge domains based on necessary knowledge types. **Solution concepts** are derived from relevant knowledge domains (i.e. basic sciences such as mathematics, physics, biology; and human sciences such as sociology and psychology). The manufacturing management and R&D management knowledge domains present tools and methods, and BM, MM and R&D management presents models. They are solution concepts because consist of joined concepts that are applied in specific contexts to achieve desired results, but also are fully developed in the prescriptive way, oriented to users (manager or decision maker) need, comprising **prescriptive knowledge**. Prescriptive knowledge is a form of solution-oriented knowledge that enables the design of propositions based on logic that allow the connection of components (i.e. solution concepts).

The selection of the correct type of prescriptive knowledge needed to connect system components or to conduct specific tasks is based on contextual features (i.e. generative mechanisms) identified by the application of descriptive knowledge (VAN AKEN; ROMME, 2009). In this sense, we can also argue that some lessons obtained from the MM literature analysis can be useful. Some models with holistic and systemic view failed in its implementation, because the models and practices "was seen as ends in themselves" (GOLDMAN; NAGEL; PREISS, 1995). This discussion is compatible with the capability view argued by (VOSS, 1995, 2005), and also with the soft elements implementation higher effectivity instead of hard elements of systems, argued by Fotopoulos and Psomas (2009). For this reason, this paper argues that the design approach mentioned by some authors of manufacturing models (GOLDMAN; NAGEL; PREISS, 1995) have to be fully developed. But the way to conduct this design is not yet discussed in this knowledge domain.

| | Manufacturing Management | Agile Manufacturing | R&D Management | Business Model | Capability Based View |
|---|---|---|---|---|---|
| **Descriptive Knowledge** | Process and activities purposes definitions<br>Related physical, chemical and biological properties and numerical and statistical summaries to describe the desired results | The need of flexibility and responsiveness obtained by alliances, core competences, long term business planning, range of markets customers, and product range | Product and services purposes and definitions, market and user needs translated into related physical, chemical and biological properties, derived from the reasoning about industrial and market evolutional stage and its configuration, concurrent products and services | No prescription regarding how to define the goal of the BM (how to act in specific contexts, market, industry, customers, to create value) | The goal of distinguishing, innovate, take advantage and to compete in the selected market and industry.<br>Results from economic, market, sociological, political, and metrological considerations, for example |
| **Generative Mechanisms** | Seasonality and other variation factors of product and services demand and mix;<br>Machines efficiency and productivity<br>Supplier delivering capability | Business characteristics, market, competition, the characteristics of products (life cycles, maturity stages) and market positions (called agility drivers) | Market and user needs, industrial, market and technological evolutionary stage, their configuration<br>National innovation system, tax regulations<br>Stakeholders needs and expectances | | The companies react to the environment, using their (limited) rationality. |
| **Solution Concepts** | Available Manufacturing equipments, techniques, and technologies<br>Chemical, physical and biological properties evaluation logics and tools<br>Logistic models (Supply chain integration level, types and configuration)<br>Some managerial concepts: Mass production; lean manufacture; just-in-time; mass customization | Agile manufacturing is presented as a solution concept to deal with the dynamic environment. It is enabled by implementing several concepts (agility enablers) regarding Integration, Competence, Team building, Technology, Quality, Change, Partnership, Market, Education and Welfare. Includes concepts as: virtual enterprise; flexible manufacturing systems; concurrent engineering; rapid prototyping tools; integrated product/production/ business information system; rapid partnership formation and organizational redesign | Available Product Components and technology<br>Chemical, physical and biological properties evaluation logics and tools<br>Several managerial practices and tools: optimization tools; Quality Function Deployment Matrix (QFD); Failure Mode Analysis (FMEA); Design of Experiments (DOE), for example.<br>Some managerial concepts: concurrent engineering; stage-gates approach; multidisciplinary team; | Some reference BMs and cases | Presents a theory to describe how organizations and economies evolves<br>Theories regarding how economies and industries work regarding what defines the competitiveness of companies in defined contexts<br>The organizational Capability concept<br>Some relevant organizational capabilities as marketing capability, manufacturing capability, innovative capability<br>Several organizational capability fitness and other characterization concepts<br>Capability lifecycle concept |
| **Prescriptive Knowledge** | Logics and concepts regarding cause-and-consequence relationship enabled by physical, chemical, and biological sciences<br>Logics regarding how to allocate and organize the equipments and procedures to design and coordinate the manufacturing process<br>Logistic optimization tools and practices | Knowledge from some other knowledge domain can be used: Some traditional human resource practices, and some strategic planning practices although not yet sufficient for the purpose<br>Some indications regarding association between the agility enablers and agility capabilities that are selected according to specific agility drivers observed in the environment | Logics regarding how to connect the components to design the product<br>Logics and concepts regarding cause-and-consequence relationship enabled by physical, chemical, and biological sciences | The BM literature presents several references BM as a result of a sophisticated decision making, experimentation and evolution of reference companies. But description and prescription about how select them or how these evolution occurs was not identified | Some ideas/theories and logics regarding how companies evolves<br>Some ideas/theories regarding logic to identify distinguishing capabilities |

**Figure 5: Comparative analysis of knowledge domains from the perspective of the design-based approach based on necessary knowledge types.**

The figure also demonstrates the theoretical nature of CBV: there are ideas, logics and theories about how companies evolves, but no prescriptive knowledge, methods or formalized cause effect relationships of how to plan, and make decisions about efficient evolution and distinguishing capabilities development, for example. Hence, we can argue that this knowledge domain comprise mainly descriptive knowledge, defined as the goals, desired outcomes, problems to be solved, and results from system dynamics and uncertainty reasoning (VAN AKEN; ROMME, 2009).

Associating the findings summarized in the Figure 5 to the previously identified commonality of objectives and weak and emergent connections (Figure 2and Figure 3), we can argue that, although described as separated knowledge domains, they present a very important complementarity because their divergent nature and research perspective, been relevant in the different components of de systems management (design stages).

## 3.3.2 Knowledge usage phases

In the following, the knowledge domains were evaluated concerning about knowledge evolution phases in the design approach, described as divergent thinking and convergent phase. **Divergent thinking phases** are responsible for problem comprehension, development of solution ideas, and elicitation of hypotheses for the creation of concepts. The divergent thinking phase begins with thought processes that involve consideration of system dynamicity and reasoning about uncertainty. Dynamicity of the environment can be defined as the conditions of an environment that are highly instable and turbulent. It occurs in an environment where changes are uncertain and difficult to predict. Dynamicity can be estimated by turnover rates, absences of patterns, and unpredictability (DESS; BEARD, 1984; DYM et al., 2005; KEATS; HITT, 1988; LUO; PENG, 1999; VAN AKEN; ROMME, 2009).

The results of the divergent phase include delivery of useful ideas and concepts for knowledge review and synthesis. The **convergent phase** employs these results to design a proposition that outlines a system. However, some specificity may not be available. Therefore, it must be complemented by the use of an evidence-based approach, estimation, and experimentation to find results that can be used for decision-making and refinement of the proposition. Both divergent and convergent phases are facilitated by the existence of a unified **language or representational** tools that foster communication (VAN AKEN; ROMME, 2009).

<table>
<tr><th colspan="2"></th><th>Manufacturing Management</th><th>R&D Management</th><th>Business Model</th><th>Capability Based View</th></tr>
<tr><td rowspan="2">Divergent Phase</td><td>Thinking about systems dynamic</td><td>The consideration to the several environmental change levels (e.g. there are several types of flexibility, comprised by volume, mix, product, and manufacturing flexibility)</td><td>The market is considered dynamic, and products must be adjusted on time because they present lifecycle. After some time, the product must be radically altered. For this reason, companies must monitor the market and customer needs.</td><td colspan="2">Several worries about systems and environmental dynamicity, with focus in their implication to organizational, supply and value chain structure</td></tr>
<tr><td>Reasoning about uncertainty and unpredictability</td><td>Uses several tools to estimate uncertainty regarding customer demands (regarding demanded volume);</td><td>Simulation tools to estimate uncertainty can be used for some product properties evaluation and definition.<br>Because the information captured from the market present significant degree of uncertainty, the products are openly conceptualized. Progressively these concept is defined, based in new information</td><td></td><td>Several worries about reasoning about environmental uncertainty<br>Capability based planning considers the uncertainty of the information captured and the volatility of the customer's and stakeholder's needs. Hence, the systems are openly conceptualized to be progressively defined based in new information.</td></tr>
<tr><td colspan="2">Language/ Representation</td><td>Architectural representation of equipments and products, electronic symbols<br>Programming language, CAD/CAM<br>Specific vocabulary from the relevant basic sciences needed to develop the technology or the product (physics, chemistry, biology)</td><td>Architectural representation of products (using CAD, for example), electronic symbols, chemical symbols, molecular structural representation<br>Programming language, CAD/CAM<br>Statistical language<br>Specific vocabulary from the relevant basic sciences needed to develop the technology or the product (physics, chemistry, biology)</td><td>BMs are representation of the organizational structure and its processes and logics to deliver value to the customer, to the stakeholders and to the market. But there are no unified language or representation rules</td><td>There are several specific vocabulary, that appears not so unified</td></tr>
<tr><td rowspan="3">Convergent Phase</td><td>Making Estimates</td><td>Product and service demand forecasting methods<br>Econometric analysis</td><td>Marketing research methods<br>Product and service demand forecasting methods<br>Econometric analysis<br>Customer clinic<br>Focus group with specialists<br>Simulation (e.g. Monte Carlo and finite element)</td><td></td><td>Capability based planning considers the specialist's knowledge and perceptions to make estimates to identify and plan the systems capabilities.</td></tr>
<tr><td>Experimentation</td><td>Design of Experiments<br>Verification, comprised by, for example: linearity, precision, accuracy, reliability, maintainability, resistance, safety<br>Statistical Process Control</td><td>Conjoint analysis; Prototyping; Assays conduction for experimentation; Design of experiments; Numerical Simulation<br>Verification, comprised by, for example: linearity, precision, accuracy, reliability, maintainability, resistance, safety</td><td rowspan="2">Literature mentions hypothesis generation, experimentation, and decision making, but no prescription regarding how to conduct it is not available</td><td>It is probable that experimentation occurs during capability engineering, but prescriptions regarding how to conduct is not available in the literature</td></tr>
<tr><td>Decision Making</td><td>Validation of engineered systems<br>Several optimization systems (software, as ERP, MRP)</td><td>Validation of engineered systems<br>Several optimization models presented in the literature</td><td>It is obvious that decision making occurs during capability engineering, but prescriptions regarding how to conduct is not available in the literature</td></tr>
</table>

**Figure 6: Comparative analysis of elements of the divergent and convergent thinking phases.**

Figure 6 describes knowledge domains (columns) with respect to the elements of the divergent and convergent thinking phases (lines). Agile manufacturing was incorporated into the MM knowledge domain. The figure show the existence of MM and R&D management tools for both divergent and convergent phase, and also standards for language and representation that enable needed communication. These tools, methods, and languages, however, are product or process oriented, not organization-oriented, a need emergent considering their development into more holistic view.

The BM and CBV, in the other hand, present no specific tools, but are more extended-organization oriented. The CBV as a theoretical domain offers several relevant concepts, and BM is worried about language and representation, although the standards or unified language must be developed inside the organization. The figure also shows another feature for the incipiency of the CBV knowledge domain, as it presents not so unified language.

The knowledge’s domain development stage or its applied nature define their commonly used research perspective. And all knowledge domains are objected to describe (or to design) a specific system (DYM et al., 2005; VAN AKEN; ROMME, 2009). The Figure 7 presents the object and research perspectives for the analyzed systems.

| | | | | | |
|---|---|---|---|---|---|
| | Manufacturing process | Extended Company | Technology/ Product/ Service/ Process | Extended Company | Extended Company |
| | Applied/ Operational Research/ Descriptive | Descriptive | Applied / design approach/ operational research/ Descriptive | Descriptive/ Applied | Theoretical/ descriptive |

**Figure 7: Comparison of knowledge domains regarding systems objects and research perspectives**

Agile manufacturing is a specific manufacturing model with not much concern about systems development and management. Thus, it can be considered somewhat more restrictive with respect to descriptive knowledge and generative mechanisms. The other knowledge domains approach goal definition tasks more openly. Decisions about products, processes, manufacturing systems, or BMs are context-dependent. Therefore, evidence-based reasoning is well established in MM and R&D management research. The BM and CBV domains are more concept-oriented, theory-based, and description-centred types of research. Thus, no concrete prescriptions exist to help companies make decisions. These domains do not provide clear instructions on the establishment of goals, although they do contain some features that should be considered based on companies’ contexts.

The MM and R&D are the richest knowledge domains with respect to the design approach. However, the BM was found to be the poorest reference point. Representation/language and convergent phase lines demonstrate that

MM and R&D are more practical knowledge domains because they present: (*a*) tools to facilitate representation and communication that can be incorporated into information systems; and (*b*) tools and practices to guide estimation, experimentation, and decision making. However, all prescriptive knowledge and practices refer to products and manufacturing processes. In addition, neither divergent nor convergent stages offer significant amounts of holistic system-oriented identification or decision tools (i.e. extended company, BM, supply, or value chain). An evolution towards prescriptive knowledge development is desirable for other knowledge domains to facilitate practical applications and elucidation for educational purposes.

Knowledge domains that consider extended companies to be objects are less developed in their design perspectives due to system complexity. Some knowledge domains and, in particular, the CBV, offer a number of solution concepts. However, other necessary knowledge types are not yet sufficiently available. With respect to descriptive knowledge, several ideas and concepts have been considered by the CBV and agile manufacturing. All of these knowledge domains include the existence of the dynamicity of the environment and the uncertainty and unpredictability. However, it is not yet clear how they can be used to define generative mechanisms needed for the selection of solution concepts and prescriptive knowledge. Prescription knowledge of the divergent and convergent phases appears to be scarce. In addition, these knowledge domains do not offer common language or representation rules. This can cause communication difficulties for the systems development team. The BM is essentially a representation. It does not present standards, definitions, or rules with respect to representation or development (i.e. prescriptive knowledge). Currently, no guides have been created that provide information on the conduct of the convergent thinking phase that is essential for the connection of components, the essence of the system design.

Therefore, the development of a complementary approach that integrates these knowledge domains may help companies apply the extended company design approach. Figure 8 outlines this proposed approach.

| | | Knowledge Domain & Proposition | Current literature/ state-of-the-art | Further Research Recommendation |
|---|---|---|---|---|
| Knowledge Types | Descriptive Knowledge & Generative Mechanisms Identification | BM: Use the ideas regarding what to consider in the systems BM goals definition | BM definition considers 'go to market' and 'capturing value' strategies: (i) products and services, (ii) activities to obtain them, (iii) the governance, organizational, and market structure, (iv) the modes of relationship with the environment (Silverman 1997; Amit and Zott 2001; Chesbrough and Rosenbloom 2002; Magretta 2002; Morris *et al* 2005; Aoki and Jackson 2007; Doganova and Eyquem-Renault 2009; Glissman and Sanz 2009; Teece 2010) | Compilation of all descriptive knowledge needed to describe the environment to guide the solution concepts selection in the designing process |
| | | CBV: Use the holistic view, exploration, and limited rationality principles | CBV consider that the company must evaluate the environment and decide how to act on it. Although some ideas are presented, it is already not sufficient to prescribe what kind of information must be evaluated | |
| | | MM (AM): Use the agility drivers and agile manufacturing objectives | Agile manufacturing model objectives are likely useful in the dynamic environment: flexibility, responsiveness, by alliances, core competences, long term business planning, range of markets customers, and product range.<br>Agility drivers must be monitored: Business characteristics, market, competition, the characteristics of products (life cycles, maturity stages), and market positions (Sharifi and Zhang 1999; Zhang and Harifi 2000; Zhang and Sharifi 2007; Zhang 2011). | |
| | Solution Concepts | CBV: use the organizational capability concept | Organizational capability concept is a change tolerant concept that enable a value chain centered view (Stevens 1998; Sawhney 2006; Hubbard *et al* 2008; Ravichandar *et al* 2008). The micro foundations of organizational capabilities are not yet well defined (Felin and Foss 2009) | In what way organizational capabilities emerge? How it can be described? How it evolves? |
| | | BM: use the holistic view, represent as a business model to enable communication, and consider it as hypothesis and transitory | Value centered and holistic decisions to guide the obtaining of the adjusted BM (Chesbrough & Rosenbloom, 2002; Fleischer et al., 2007; Hubbard et al., 2008; Sawhney, 2006; D. J. Teece, 2010). The literature just mentions some possible configurational elements, one suggestion is the organizational capabilities, especially for dynamic environment context (Fleischer *et al* 2007). | How to use the organizational capability concept to design a business model? |
| | Prescriptive Knowledge | MM& R&D: Use the evaluation tools | Several tools regarding market, customer, competitor and technology evaluation are available<br>Several evaluation, diagnostics and decision making tools | |
| | | CBV: use CBV concepts to select adequate capability configurations | Performance related concepts that allow acknowledging about flexibility and adaptability in the dynamic environment (Barney, 2001; Capron & Mitchell, 2009; Laamanen & Wallin, 2009; Lavie, 2006). | It is needed some prescriptive knowledge to use the concepts |
| | | CBV: Plan the Business model considering the organizational capability | The capabilities present four dimensions: knowledge and skills, technical systems, managerial systems, and values and norms (Leonard-Barton 1992). In the Capability Based planning, the organizational capabilities are planned considering process, products, technology, facilities, doctrine, organization, training, material, education, people, and resources (Stevens 1998; Davis *et al* 2008; Garvey 2009; Yue and Henshaw 2009). | How it organizational capabilities can be planned and made decision making regarding them? |
| Language/ Representation | | BM : use BM as a representation tool | BM are defined as representation, but no rules nor standards regarding how to represent them are presented | Creation of guides about how to represent the BM |
| Divergent Phase | | CBV, BM & MM: use the Descriptive knowledge and generative mechanism identification presented above | | How to evaluate? How to monitor, as environmental changes can occur? And new information can be captured as the technologies evolve and the industry and market matures? |
| | | MM& R&D: Use the environmental evaluation | Several tools regarding market, customer, competitor and technology evaluation are available | |
| Divergent Phase / Convergent Phase | | R&D: Use the open-concept definition and continuous concept refining process | Stage gate and milestones approaches enables a continuous refining process | Prescriptive tools for Capability based systems development |
| Convergent Phase | | CBP (CBV): Plan the business model estimating the needed capabilities | Evolution process is considered a learning process comprised by experimentation. Any primary signal of failure must be monitored to act quickly to develop a correction to the business archetype. The use of organizational capabilities as unit of analysis for BM evolution enables a change tolerant performance measurement system (PMS). The capabilities planned configurations (requisites) are evaluated if they are yet suited, considering the environmental changes (Ravichandar et al., 2008; Stevens, 1998). | Development of decision making tools: Capability based PMS development; Capability based technological scenario planning tool; Capability based business model engineering hypothesis testing guide |
| | | Capability Engineering (CBV): monitor the systems evolution | | |

**Figure 8: Proposition for the unification of knowledge domains based on the evolution of the design approach and further development needs.**

This paper proposes the amalgamation of: (*a*) the holistic view of agile manufacturing, BM, and CBV knowledge domains; (*b*) the evolutionary and learning approach enabled by BM and CBV knowledge domains; (*c*) open-concept definition and continuous concept refinement logic presented in the R&D knowledge domain (already shown in the CBP); and (*d*) practical and operational perspectives of MM and R&D management that consist of optimization-focused (operational research derived) prescriptive tools and practices development approach.

The main discussion regarding ***holistic view*** rescue in both MM and R&D management is regarding the transference of small systems (product or manufacturing process) focus to the extended company focus. The systems development, evaluation and optimization way of thinking is maintained. So, this holistic view is allowed by incorporating organizational learning perspective in these knowledge domains. The holistic view can be restored not just by the connection of R&D and MM, and agile manufacturing, but by the conceptualization of the BM as an outline of the ways that a company acts in its environment. It can include strategy discussions. BM engineering can be useful as a motivational guide for discussions about organizational (and supply chain) planning. However, it requires theoretical and practical complementation and further development. Organizational learning, organizational capability, and the importance of soft components were identified as key elements for the evolution of the BM. ***Evolutionary and organizational learning*** approaches can be observed in BM, CBV literature, and, to a certain extent, in agile manufacturing literature. The CBV offers a theoretical basis presenting organizational capabilities acquisition, creation, evolution and fit logics. Agile manufacturing implementation descriptions employ both traditional best practice and capability-related concepts. Agility providers are the tools and practices that should be implemented to achieve agile capability. In other words, they might be described as best practices by the CBV.

The discipline of system engineering demonstrates that the existence of components is not sufficient for system development. During the capability planning process, capabilities can emerge only from the efficient integration of components. Therefore, to enable effective BM development (and, for example, to obtain necessary agility configuration), the implementation of best practices is not sufficient. It is necessary that knowledge and abilities be added to the practices, principle, and logic adopted from related knowledge domains. These are referred to as **soft components**. They include doctrines, processes, human behaviour standards, and beliefs. These soft components are employed to combine and integrate other components in a logical form to enable system capabilities. For this reason, agile manufacturing requests that agility providers be integrated into the organizational context (ARTHUR, 2010; CALVANO; JOHN, 2004; HITCHINS, 2007; SHARIFI; ZHANG, 1999; ZHANG, 2011;

ZHANG; SHARIFI, 2007; ZHANG; HARIFI, 2000). This rationale results in the adoption of a new structure and new organizational logic. This can then be depicted by graphic or semantic representations and will be known as the BM.

Therefore, the simple integration of knowledge domain concepts is not sufficient. The researchers must develop prescriptive knowledge that describes the ways they can integrate solution concepts offered by knowledge domains. R&D and MM became efficient in the engineering of products and processes by the incorporation of tools and methods (i.e. prescriptive knowledge) generated by the operational research approach. With respect to extended company development, deficiencies of prescriptive knowledge (i.e. operationalization tools) have been observed. For example, although the BM knowledge domain is practice-oriented, no decision-making tool focussing on BM development was observed.

To contribute to a practical and applied design approach, a design-based knowledge domain should contain prescriptive knowledge formalized in tools, practices, and methods that can be employed to guide companies during the divergent phase as well as during the decision-making process during the convergent phase. Hence, based on the practical and operational perspective of the MM and R&D management, the need for optimization-focused, operational research-derived development of ***prescriptive tools and practices*** is crucial.

The BM has been presented in the literature as a representational tool that facilitates communication, discussion, and hypotheses elicitation for organizational evolution. However, each BM, in its graphic representation, was developed based on specific languages and rules developed by each company. There is no defined method for the design, planning, or testing of hypotheses during organizational evolution. This strongly suggests the need for prescriptive knowledge development that includes standards and rules for the formalization of logic in the representation of BM's.

With respect to organizational learning and evolutionary concepts stressed in the CBV and BM, development is necessary to facilitate the convergent phase by the use of evidence-based estimation, experimentation, and decision making. Currently, the incorporation of organizational learning and organizational capability concepts in BM literature is not clear. The lack of prescriptive knowledge is the main concern for the design approach to extended company engineering based on the CBV conceptual background. One idea that may be useful for further development is the ***open-concept definition*** and the continuous concept that refines process logic that can be observed in R&D and in Capability-based Planning (CBP, based on the CBV) processes. This is compatible with organizational learning concepts.

It can be argued that the CBV can be a useful guide to the monitoring and decision-making processes involved in BM evolution for new enterprise planning and performance measurement processes. One reason for the limited utility of the CBV is the absence of micro-foundations of organizational capabilities that should reveal how it emerged, how it can be described, how it evolved, and how organizations can specifically learn from it. Some prescriptive knowledge generation trends have been founded on the following assumptions:

a. The CBV literature presents concepts that suggest several metrics for performance measurement that allow the acknowledgement of flexibility and adaptability in the dynamic environment.
b. The CBV allows value-centred and holistic discussions to guide the procurement of the adjusted BM.
c. The use of organizational capabilities as a monitoring unit for BM evolution can enable a change-tolerant performance measurement system (PMS) approach.
d. The CBV allows that decisions taken in the capability development process are based on the search for internal and environmental fit (contingency approach).
e. The PMS must agree with the ways that organizational capabilities are achieved (e.g. processes and routines developed and knowledge integration).
f. The CBV considers the relevance of traditional best practices as a type of time- and context-specific, transferable (and imitable) solution for capability.
g. The CBV bears in mind that effective capability development occurs by the use of organizational learning. Hence, organizational structure must also agree with dynamic capabilities.

## 4. CONSIDERATIONS

This paper provided theoretical discussions that compared different but related knowledge domains: the Manufacturing Management, the R&D, the Business Model, and the Capability-Based View. The literature review discovered similarities in discussion themes and objectives. An analysis inspired by the design-based approach provided an evaluation of the composition of knowledge domains with respect to solution concepts, descriptive and prescriptive knowledge availability, and possible courses for integration. The paper presented practical discussions with respect to BM literature along with discussions of proactive flexibility and agility planning. These discussions enabled the contextualization of Manufacturing Management discussions in the context of R&D, Technological Development and innovation, characterized as the dynamic environment.

This paper suggests that the BM engineering discussion can be used as a motivational stream to unify knowledge domains concepts, principles, and tools. It also identified the need for prescriptive knowledge development based on CBV concepts to enrich the management of the manufacturing – R&D interface. Further, it also presents some questions and suggestions for further development that should be addressed by future research.

These suggestions highlight the need for intensification of multidisciplinary and interdisciplinary research. The short literature review demonstrated that there are several discussions regarding the rescue of the connection between R&D and manufacturing, presenting several tools, methods and models. This paper does not exhaust all possible knowledge domains or disciplines, but this paper remembers that this discussion is present in several other research lines and disciplines. As all these disciplines discuss the same (or at least much related) objects, the unification or at least consulting some other disciplines is needed.

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