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Influence of knowledge on the innovation value chain performance in the product development process

Selma Regina Martins Oliveira and Roberto Sbragia

Department of Business Administration,
University of São Paulo,
São Paulo, Brazil

ABSTRACT: Recently, relevant changes have made organizational boundaries more fluid and dynamic in response to the rapid pace of knowledge diffusion, and innovation and international competition. This helps to reconsider how to succeed with innovation. Thus, innovative companies make use of their capabilities to appropriate the economic value generated from their knowledge and innovations. Therefore, the supply of innovative products is presented as a quality standard in the race for pressing demands. It is true that a new product or process can represent the end of a series of knowledge initiatives and the beginning of a process of value creation, which, under conditions imposed by various parties, can produce efficient results in the global performance of the value chain. The present paper aims to contribute to the planning guidelines in the innovation value chain field. Therefore, it addresses the influence of the stakeholders' knowledge on the performance of innovation value chain in product development processes applied to technology-based companies. Thus, a survey was developed with experts chosen by their technical-scientific criteria and knowledge on the subject. The data were extracted by means of a judgment matrix. To reduce subjectivity in the results, the following methods were used: Law of Categorical Judgment - psychometric scaling and the Compromise Programming - multi-criteria analysis and Electre III. The data were satisfactory, validating the methodological procedures presented.

KEYWORDS: Knowledge, Innovation Value Chain, Product Development Process, High-Tech Industries.

1 INTRODUCTION

Recently, relevant changes have made organizational boundaries more fluid and dynamic in response to the rapid pace of knowledge diffusion, and innovation and international competition. This helps to reconsider how to succeed with innovation. Thus, innovative companies make use of their capabilities to appropriate the economic value generated from their knowledge and innovations. Therefore, the supply of innovative products is presented as a quality standard in the race for pressing demands.

Developing products is not a recent phenomenon, but reconstruction presents successful and unsuccessful experiences. And any attempt to encourage reconstruction and interpretation refers to, first of all, a proper analysis of the difficulties and peculiarities of the product development chain, the "opposite semantics due to the systems' diversity of features – structures, methods and organization". The reconstruction then uses a "mantle" that takes advantage of the experience accumulated by the actors in the product development process of the value chain, considering the learning process for the construction of knowledge. In any case, product development is a complex chain of events and decisions, which can break at any of the weakest link: some projects lost due to unrealistic predictions or the absence of its real role in the agenda, or other motivations that somehow followed ideas that had many missteps or a detail error.

It is true that a new product or process can represent the end of a series of knowledge initiatives and the beginning of a process of value creation, which, under conditions imposed by various parties, can produce efficient results in the global performance of the value chain. The value chain management – VCM has for quite some time presented challenges within a wide diversity of extremely complex events, all of which in an unsure and risky context that can affect the flux of decisions and the desired levels of performance, hence frustrating expectations for stability. It must be acknowledged that risks can be brought about from different origins and scenarios. With time, this eventually leads to changes in the configuration of the chain. Consequently, it is considered one of the main challenges of value chain management, which basically consists of creating integrated structures of decision making in an extensive universe containing multiple organizations. This requires an integrated and shared decision structure that involves key business processes, concerning efficient coordination of functional-temporal company-client [1] [2] [3] [4] [5] [6] [7] [8]. The characteristics of the value chain differ a great deal, therefore becoming the object of analysis equally differentiated.

One of the aspects that deserves to be highlighted is the occurrence of errors in the management of the value chain, which often results in a non-fulfillment of the established goals and performance. It is imposed thus that the efficiency in the planning of the value chain propitiates more efficient decisions, diminishing the improvisation and improvement of the involved team. Traditionally, the planning phase "sins" when it is elaborated without support of the knowledge that really is essential in the management of the value chain. The knowledge may represent a strategic tool, increasing the institutional capacity of the Entrepreneurs in their assignments of formulation, evaluation and execution of such projects. In this spectrum, the present paper aims to contribute to the planning guidelines in the innovation value chain field. Therefore, it addresses the influence of the stakeholders' knowledge on the performance of innovation value chain in product development processes applied to technology-based companies. Within this context, this paper is structured according to the following sections: methodology, results and analysis; the paper concludes with the final considerations.

2 METHODOLOGY: STEPS AND IMPLEMENTATION

The objective of the methodological procedures used is to achieve the intended goal and solve the research problem. This research is characterized by a combination of sequential qualitative and quantitative approaches. The data are extracted (Judgment matrix) at two stages, based on the specialized literature to identify the knowledge variables of the stakeholders. These variables will then undergo confirmation and judgment by the experts, through a survey, in technology-based companies (in Brazil). Firstly, the degree of influence of the stakeholders' (sources) knowledge on the overall performance of the innovation value chain in technology development process was investigated in technology-based companies. The support methods used were: Compromise Programming, Electre III and promethee II. And to confirm the reliability of the results produced by the LJC Psychometric Scaling Methods and Multicriteria Method.

SAMPLE AND DATA COLLECTION

This section details the elements that comprise the sample as well as the data extraction structure used in the study. Thus, the data were first extracted from the specialized literature on the subject under investigation to prepare the scalar-type data collection instrument (assessment matrix), based on Thurstone's law of Categorical Judgment psychometric scaling method. Once the construct and content were defined, the instrument was submitted to the experts' (judges) assessment in order to confirm the scale with regards to construction and content. Thus, the stakeholders (knowledge sources) from diverse backgrounds and scenarios, directly and/or indirectly involved with the technology developing process in the innovation value chain in PDT were identified.

We first identified the following stakeholders (knowledge sources): (i) research and development - R&D [9]; (ii) Customers [10]; (iii) Suppliers [11] [12]; (iv) External consultants [11]; [12]; (v) Competitors [13] ; [14]; (vi) Joint ventures [13];[14]; and (vii) universities/other public research centers [15]. After the knowledge sources survey, the stakeholders' main spectrum of activities considered in the PDP/TPD were identified. The activities identified were: I – Project Scope; II – Concept Development; III – Prototype Development; IV – Integration of Subsystems; V – Prototype Production; VI – Market introduction; VII – Post Product Launch. It should be noted that the activities presented for the case in question are for the technology development process (TPD). The results obtained are as follows: I – Invention; II – Project Scope; III – Concept Development; IV – Concept Development; V – Technology Optimization; VI – Technology Transfer.

After identifying the technology development stages, the next step was to identify the knowledge needed to converge each of the stages in the PDT stages. The results showed the following knowledge according to the PDT steps (Clark and Weelwright, 1992; Clausing, 1993; Cooper and Kleinschmidt, 1987; Reis et al, 2006; Creveling, Slutsky and Antis, 2003): (i) Strategic Planning of the company; (ii) Technology Strategy determination; (iii) technology; (iv) consumer; (v) Generation of ideas; (vi) project scope development; (vii) mapping future plans; (viii) patent survey; (vix) identifying opportunities; (x) identifying potential ideas under certain conditions through preliminary experiments; (xi) identifying necessary resources and solutions for the shortcomings identified; (xii) projection of product platforms; (xiii) creation of QFD for technology

(technology needs); (xiv) conducting available benchmarking technology; (xv) development of partner networks; (xvi) defining new technology functionalities; (xvii) identifying technology impact on the Company; (xviii) documents analysis and generation of technology concepts; (xix) selection and development of the superior technology concept; (xx) definition of commercial products and processes and possible processes; (xxi) decomposition of system functions into subfunctions; (xxii) definition of system architecture; (xxiii) definition of system architecture; (xxiv) use of mathematical models that express the ideal function of technology; (xxv) prototype development and testing; (xxvi) identification of market impact and manufacture of these possibilities; (xxvii) preparation to implement the business case; (xxviii) identification and evaluation of critical parameters; (xxix) technology optimization from its critical parameters; (xxx) analysis of factors that can result in platforms; (xxxi) development of the platform subsystems; (xxxii) carrying out optimizing experiments; (xxxiii) design of integrated subsystems platform; (xxxiv) system performance tests; and (xxxv) defining the technology selection criteria. Thus, the influence of the stakeholders' knowledge on the performance of innovation value chain in PDT under constraint and uncertainty was based on the activities and their respective technology development stages.

Taking into consideration that development projects of new technologies involve high risks and uncertainty (Cooper, 2006). To reduce the risks and uncertainties of innovative projects in this research, the analogy of [16] was applied, which proposes executing various activities throughout technology development, considering that there is an organized arrangement among them, hence enabling to better manage the process. These projects are not developed properly, influenced by the instability of technology and markets that change unexpectedly. Furthermore, these projects can be developed as part of product designs, causing conflicts when developing an innovative product [17]]18].

After this procedure, the performance dimensions of the innovation value chain in TDP were identified (based on the literature). The results showed the following dimensions: customer impact, business and sales return derived from innovations. For the case in question, the influence of knowledge on the overall performance of the innovation value chain was considered. Next, we identified the influence of knowledge according to the dimensions individually considered: customer impact, business return and sales percentage derived from innovation. Technology-based companies are organizations that structure their activities in the development and production of new products and/or processes, based on the systematic application of scientific and technological knowledge and the use of advanced and pioneering techniques. These companies have knowledge and technical-scientific information and a high rate of R&D expenditures as their main input. The main element that distinguishes this category of companies from others is the risk of activities that includes innovations. And this is because they operate in specific sectors with non-standard technologies.

The influence of knowledge on the overall global performance is detailed in the next section, using the LJC psychometric scaling method, as well as the influence of knowledge according to each performance dimension of the value chain using the Multicriteria Analysis method: Compromise Programming, Electre III and Promethee II. In summary, the results were extracted from the literature and then confirmed and validated by experts that were selected by their technical-scientific criterion on the object, with their experiences/practices and/or knowledge about product development, technological innovation and organizational management in technology-based companies in Brazil. Twelve experts were selected. The instrument was submitted to the experts via e-mail and through personal interviews. The final response rate was of 80%. More than half of the respondents were managers or supervisors, followed by senior managers (general manager or director), representing 40%. The remainder held or hold various management positions in technology innovation and product development. The results are detailed to follow.

3 RESULT AND ANALYSES

Monitoring the innovation value chain performance from a knowledge management perspective requires that the appropriate monitoring procedures are in place and operational [5] ; [8]. These procedures will of course depend on the kind of measures taken earlier and must be tailored to them. But it is not only improvement plans that must be monitored. Generally, a keen eye must be kept on the knowledge household of Value Chain Management. Especially important is watching the external environment for new events that may have impacts on the way Value Chain Management deals with knowledge shown as "incoming" arrows that will influence the execution of the knowledge management cycle.

3.1 INFLUENCE OF KNOWLEDGE ON PERFORMANCE IN VALUE CHAIN INNOVATION: THURSTONE'S LJC METHOD

As referenced earlier, the influence of knowledge on overall performance was conducted by means of the Thurstone's LJC psychometric scaling method. The method allows a scale by importance. The experts (judges) express their preferences with pairs of stimuli (knowledge), and these were submitted to the ordinal categories C1=5th place; C2=4th place; C3= 3rd; C4=2nd place; C5=1st. The procedures to apply the instrument are systematized in the following steps: Step 1: Determining the frequencies of preferences for pairs of stimuli (Knowledge), where O_i is equal to Knowledge and O_j to the experts – $O_i]O_j$. The systemized data were extracted from the experts' preference regarding Knowledge (through field research using an assessment questionnaire/matrix). Knowledge appears as stimuli submitted to the ordinal categories. Step 2: Determination of the frequencies of ordinal categories, based on the data extracted from the previous step. The matrix [πij] of the cumulative relative frequencies is then calculated. The results are classified in ascending order of importance. To better understand the technique, we recommend the following literature [19] [20]. Step 3: To determine the matrix [πij] of the cumulative relative frequencies from the results of the frequencies of ordinal categories we calculate the matrix of the cumulative relative frequencies. Step 4: To determine the inverse of the standard normal cumulative frequencies (INPFA), from the results obtained in the previous step, calculate the inverse of the standard normal cumulative frequencies. The results reflect the experts' preference probabilities in relation to stimuli (knowledge). . The results are detailed to follow.

Table 1. Probability Intensity of Knowledge Influence on Performance in the Innovation value chain

Knowledge (Stimulis)	C1	C2	C3	C4	($\mu i = -\sum_{j=1}^{4} Zij/4$), TOTAL	Ranking
R&D	-1,22	-1,22	-1,22	-0,76	-4,43	**1º**
External consultants	-1,22	-1,22	-0,14	1,22	-1,36	**7º**
Suppliers	-1,22	-1,22	-0,76	1,22	-1,99	**5º**
Joint ventures	-1,22	-1,22	-0,43	1,22	-1,65	**6º**
Competitors	-1,22	-1,22	-1,22	0,43	-3,23	**3º**
Clients	-1,22	-1,22	-1,22	-0,13	-3,8	**2º**
Universities/ research center	-1,22	-1,22	-0,76	0,43	-2,78	**4º**

The application of Thurstone's LJC method, of mental decision, resulted in the preferences obtained ($\mu i = -\sum_{j=1}^{4} Zij/4$), in order of increasing priority. The order found was: first the R&D knowledge and in second place the knowledge generated from Customers. Investment policies have been strongly oriented to R&D. R&D has become a strategic development leverage for companies seeking to achieve world class status [21]. The presence of R&D creates an organizational setting that is favorable to questioning, promoting corporate/company flexibility, with an ability to integrate new concepts and adaptability to market changes [22]. In addition, the knowledge and past experience gained with R&D, as well as their lasting and not sporadic existence, renders it instrumental to innovation [23]. Studies on R&D efficiency have many applications as a management tool. R&D is strong performance measure, similar to ROI. It can also be used as a means of comparison (benchmark). R&D efficiency is also an aggregate measure of the overall success of a company's product in the development effort. R&D brings the percentage of researchers employed; success rate of R&D products; patent number and R&D intensity; the decision for innovation capacity informs the degree of innovative R&D ideas; the collaboration intensity with other companies or R&D centers; R&D sharing capacity; forecast and evaluation of innovative technology initiatives for business innovation.

Within this outlook, it is possible that R&D is the central component of firms' technological innovation activities. It is believed that the organizational efficiency in these activities that lead to innovation enables the firms to achieve the satisfactory and desired performance, traditionally measured by sales growth, net income growth and return on investment. R&D and innovation are susceptible to sectorial influences [...] [24]. Product innovation is considered stronger in high-technology sectors [...] [25]. Moreover, the central element is the internal role of R&D to maximize the benefits of innovation from other forms of knowledge [26] . It should be noted that companies with a strong customer focus are able to anticipate the needs of current and latent customers [27]. [28] state that customer-focused companies focus on Product innovation versus process innovation and continuously collect information on the needs of competitors and target customers, and check their ability to use this information to create superior customer value. A company's strong customer-focus can lead to an emphasis on innovation that is derived from the desire to continually adapt to customer needs [29]. [30] calls attention to the fact that client knowledge enables the companies' regrouping and creation of incremental value. And within this perspective, [31] show that companies should take every opportunity to interact with customers in order to enrich their customer knowledge base. Consequently, a company can gain a thorough understanding of its customers, thus better able to meet their demands.

3.2 INFLUENCE OF KNOWLEDGE ON THE PERFORMANCE OF INNOVATION VALUE CHAIN: MULTICRITERIA METHOD

To execute this step the multicriteria method was used: Compromise Programming, Electre III and Promethe II. The multicriteria method was chosen due to its flexibility for the case in question, especially the subjective nature of the variables involved and the problem to be solved. The methods' application anticipates weight inferences to the evaluation criteria, expressing their relative importance. The relationship of significance between the evaluation criteria should reflect the stakeholders' resulting values within the study's scope of application, considering their specific expectations for each criterion. In this spectrum, defining the criteria weights is characterized as a group decision-making problem, which includes identifying the stakeholders' preferences and consensus.

The definition of the evaluation criteria weights used in this work proposal was prepared by the experts, through a judgment matrix. With the judgment matrix results, these methods were applied: Promethee II, Electre III and Compromise Programming, to evaluate the stakeholders' knowledge influence on the value chain performance considering each of the performance dimensions. Thus, these are the stakeholders identified: (i) R&D; (ii) Clients; (iii) Suppliers; (iv) External consultants; (v) Competitors; (vi) Joint ventures; and (vii) universities/other public research centers, which here are considered as the independent variables. The performance dimensions: customer impact and business return, were considered as dependent variables. The results showed the following classification:

Table 2. Performance of the stakeholders' knowledge on the innovation value chain performance: Compromise Programming, Electre III and Promethe II

Stakeholders' knowledge (Sources)	Ranking		
	Promethee II	Compromise Programming	Electre III
R&D	1°	1°	1°
Clients	1°	1°	3°
Suppliers	3°	3°	2°
External consultants	4°	4°	2°
Competitors	2°	2°	3°
Joint ventures	4°	4°	4°
Universities/other public research center	2°	2°	3°

Both methods (Compromise Programming and Promethee II) indicate R&D Knowledge and Customers as the most relevant to ensure performance of the innovation value chain in PDT.

When comparing the results in terms of performance, the methods Compromise Programinng and Promethee II did not differ in their classifications. As for Electre III, the results were divergent. This is due to the veto threshold p, q and v, respectively, of indifference, strong preference and veto or incomparability, moreover, there is a discrepancy in the structure of its results (classification). Electre III features a solution group with a more flexible hierarchical structure. This calls attention to the method conception itself, as well as the quite explicit consideration of indifference and incomparability between alternatives. As an advantage of this structure of results, an easier consideration of the most difficult aspects to address and an analysis can be concluded, enabling a final less rigid hierarchy, around a small group of alternatives that can also be classified as better options.

The alternatives that exhibited some measures of incomparability were classified as other alternatives, which did not feature the same characteristics, and which were placed in a situation of disadvantage, regarding other criteria. It is observed that such alternatives are not comparable with any other alternative. Similar to the incomparability feature, another important characteristic of the methods Electre III and Promethee II is intransitivity. Considering that Compromise Programming is based on the distance of the alternative evaluated as an "ideal solution" vector, it is then concluded that this method has transitive features. Thus, the methods that better performed to ensure performance of the innovation value chain in PDT are: Compromise Programming and Promethee II, which resulted in the following classification in decreasing order: (^{1st}) R&D customers; (^{2nd}) Competitors and Universities/Research Centers; (^{3rd}) Suppliers; and (^{4th}) External Consultants and Joint ventures. The results referenced by the methods "Promethee II" and "Compromise Programming" reflect the preference, in the experts view, by R&D knowledge and Customers, with 68% and 59% of the preferences, respectively. Within this perspective, the multicriteria methods are viable instruments to measure the performance of the innovation capacity dimensions for the performance of high-tech companies. The results produced by this prioritization enable managers to better focus their efforts and resources on managing the capacities that perform best, which results in achieving the goals sought by the companies.

4 Final Words: Lessons Learned

The objective of this study was to contribute to the planning guidelines in the innovation value chain field. Therefore, it addresses the influence of the stakeholders' knowledge on the performance of innovation value chain in product development processes applied to technology-based companies. The study strived to fill a gap in the existing literature on the value chain performance from the perspective of knowledge in the product development process. Thus, a set of psychometric scaling methods, multicriteria analysis was conceived. This procedure enables to reduce the subjectivity in the results achieved. The compelling presupposition assumed is acknowledging the importance of subjectivity in the decision-makers' judgment; their values, their goals, their biases, their culture, their intuition, as well as the influence of subjective factors on the perception and understanding of the variables involved.

Decision-making processes play an important role in product innovation processes. In every stage of the process decisions are made about the progress of the project [32]. The high demand for innovative products has been treated as a challenge for the adoption of traditional project management (PM) practices and methods, specially those ones developed in turbulent and complex business environments. Product development process (PDP) has received special attention from companies due to it is recognized as a source of competitive profits. Continued innovation of products, services, technology and the organization itself, has been one way to keep a business on its feet during the turbulent 1990s [33].

Through its systematization companies can reduce theirs costs and development time and increase their product quality. The dream scenario for thousands of businesses would be to gain the ability to get their products to market faster, and to know with some certainty that their product-development projects would be completed on schedule. Thus, The present work intends to contribute to the innovative planning guidelines in the field of product development. The knowledge may represent a strategic tool, increasing the institutional capacity of organisations and the Entrepreneurs in their assignments of formulation, evaluation and execution of such projects. The knowledge would work as a facilitator instrument of improvement, contributing for the quality of services and the enhancement of the agility to decide.

Within this spectrum, this paper investigated the influence of the stakeholders' knowledge on the performance of the innovation value chain in product development process applied to technology-based companies. Several conclusions can be drawn from the results of this research. It is essential to measure the contribution of knowledge in the value chain performance. The performance of the value chain is an interdisciplinary and multidimensional concept that considers several areas of knowledge. The sample data supported the conceptual model derived from the literature. The confirmation of the general model proposed was important because it empirically evidenced that knowledge from R&D sources is considered the greatest influence on the performance of innovation value chain. Even if it is simply the probability intensity of the influence of this knowledge on the PDT innovation value chain.

The results obtained have been satisfactory, validating the proceeding proposed for assembling and prioritizing critical knowledge for research and development (R&D), as well as for comprising other elements of performance in the innovation value chain. Thus, this paper is aimed at an important area in Brazil. The current challenge is to develop knowledge systems to collect, distribute and disseminate information/knowledge to enable and facilitate policy development for the early implementation of innovation projects in product development. In this scenario, our methodological contribution is highlighted, because it provides support to the critical priorities in order to implement this project, and is also directed to building up knowledge as a key element for product development.

We look forward to a more practical and efficient orientation that supports its long-term goals, thus assuring national competitiveness concerning the category of priorities. By gathering the cognitive elements, it can be seen that this strategy requires a priority dynamics, which depends on the initial state of product development process, on the concrete characteristics of the projects and on an innovation policy and cognitive problems that emerge during practice, always placing in view new contents. For this, priority research must be permanently and recurrently applied. Moreover, it is important that this method be used in other applications. Also, it is recommended testing the hypothesis by giving the decisions environment of that category of projects an intelligent treatment, by means of this research's systematic knowledge, which makes decisions more efficient concerning the development and management of product development projects.

Few studies have investigated the influence of knowledge on PDP under constraint conditions. It is hoped that this study will stimulate a broad debate on the issue and it is acknowledged that more studies are needed to build more robust results in the near future. In addition, the study is limited to technology-based companies, opening the possibility for significant results. Moreover, the measurement of qualitative variables is a highly subjective factor. All data were collected transversally, and therefore what can be concluded is that the variables and their effects are related to a single point in time, thereby showing a limiting factor.

Finally, there may errors deriving from various origins such as incomplete sampling bases, among others. Some key priorities are proposed for future studies. We acknowledge the importance of replicating this study and repeating this testing model approach, using a completely new sample from other sectors. Interesting comparisons could also be carried out, as for instance applying the procedure adopted here in another country, in order to compare the results. Within this spectrum, this methodology does not claim to be complete, but it is our intent to make it a generator of strategic elements for the development of innovation projects. This is where the knowledge Management becomes important, since it is a key instrument for project development in such a complex issue, as it is the case of product development.

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