Developing technological industrial products in a periphery framework

Desarrollo de productos industriales tecnológicos en el marco de la periferia

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Abstract

The technological analysis of product development dynamics in the periphery initially involves the conceptualization of 'technique' and 'technology' as forms of knowledge building and as means of production. A benchmark was accordingly defined to determine the key components of a product development process within a technological context, which is related to the industrial context provided by the periphery that, in the Latin American context, involves small and medium enterprises (SMEs). This project was structured accordingly and aimed to design a tool to analyze product development processes in SMEs from a technological viewpoint.

Key words: Technique; technology; product development; periphery.

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Introduction

After developing the epistemological concept of 'technique' and 'technology', based on the work of Ortega and Gasset (1982), Ladriere (1977), Mitcham (1994), Meijers (2009), and Bunge (1960), technology appears to be the right approach to industrial product development. In synthesis, technique and technology are developed using two similar dynamics and sharing the same objective, but diverging in the method used. In the case of a technique, the environment is transformed by man, after receiving training and adopting a technology. Regarding the method used, a technique occurs in fortuitous conditions, not known or understood by man and therefore out of his control. Technology, on the other hand, involves a more elaborate knowledge-building process, which embraces the scientific method and therefore involves testing under known or predefined and controlled conditions for a specific purpose.

To determine whether a technological process or a technical process is the most appropriate, there should be a certain symbiosis with product development dynamics, which in this study was based on the work of Ulrich and Eppinger (2009), along with the respective contextualizing of Colombia's industrial panorama of small and medium enterprises (SMEs). This project was designed based on three project components—technique-technology, product development, SMEs—and aimed to build a tool for analyzing the technological aspects of product development in SMEs. This tool requires high levels of objectivity through the continuous building of technological knowledge through ongoing evaluation and selection.

Methodology

The development of the project's conceptual framework was based on three main fronts:

• *Technique and technology*. The epistemological analysis of the concepts of 'technique' and 'technology' is pertinent to establish their specific operational parameters and particular characteristics, constituting the bulk of research.

• *Product development processes.* A correlation was subsequently established with product development phases, which were organized based on studies conducted by the National Institute of Industrial Technology (INTI, its Spanish acronym) in Buenos Aires, Argentina, and pertinent observations made by authors such as Ulrich and Eppinger (2009).

• *Local industrial context.* To complement the above, it was necessary to define the characteristics of the national industrial sector and accordingly identify its characteristics and performance within the metropolis-periphery relationship and thus develop a solid conceptual framework.

A technology analysis matrix was finally developed, based on the relationship between product development phases and technology, represented mainly in the dynamics of the scientific method. The relationship was built, based on the economic opportunities, logistics, and needs of SMEs and the industrial context of the periphery. Five major phases of product development resulted, along with their respective technical and technological operations and their quantification parameters, which guaranteed an objective assessment using a ranking system consistent with established technical and technological aspects.

Controversy and relevance of technology in product development processes

Ambiguity was, however, evident after addressing the main issue of whether technology-based product development was appropriate or not. Most product development strategies shared worldwide are, in some way, technological strategies. All have components that are interlinked, that quantify and evaluate, and that yield results, organized under the provisions of the scientific method. But, if product development using technological dynamics is the best alternative for developing a site-specific technology, why is it not always effective?

Although the answer to this question has multiple and complex fractal variables, this study placed emphasis on two variables: (1) creativity and (2) unstructured problems, as called by Bonsiepe (1978) and referring to problems or conflicts that lack a scientific explanation or are, at the least, insufficiently defined. An individual's inclination to select one product over the other obeys a series of factors (preference, mood, day-to-day peculiarities, etc). Every human creation (whether artistic, industrial, linguistic, or other) is inherent to the creative component, significantly influencing the technological development of industrial products and this is where divergence occurs. Technology comprises parameterization and quantification of components and knowledge for further evaluation and achievement of objective-driven results (scientific inheritance); however, it is difficult to quantify creativity/creative processes and unstructured problems.

According to Bonsiepe (1978), industrial designers, who are sometimes accused of being irrational, are attributed the area of aesthetics and superficial, non-technical, or peripherally technical aspects of design. Engineers, on the other hand, are attributed the truly rational and technological aspects of design. This unproductive dichotomy was based on a concept of positivist rationalism in which rationality only appeared when dealing with quantification. Obviously, industrial designers solve problems arising from unstructured situations and are therefore knowledgeable in non-quantitative methods to address those dimensions of project-related issues where quantification procedures have limited application and prove inadequate. The figure of industrial designer is irrelevant in the case of this study; however, the situation described by Bonsiepe above corresponds precisely to one of the obstacles faced during technology-based product development. As Bonsiepe stated, parameterization and quantification have a limited scope and it would be too pretentious and inefficient to submit all the variables involved in the development of a product to the technological approach. Therefore technology can only manipulate, to a certain extent, the creative process as well as unstructured problems, human perception, preferences and rejection, aesthetics, and so forth.

For example, there is a radical difference between developing a commercial vehicle and a lunar roving vehicle. The building of both is quite similar in technological aspects, but differs in specificity aspects. In terms of development, the requirements governing the effectiveness of the lunar rover are solely determined by how it performs its tasks, so it's completely objective at a scientific level, whereas a commercial vehicle faces a series of subjective requirements related to the unstructured problems aforementioned by Bonsiepe: human perception and social, cultural, and political contexts, among others. These problems must be addressed together with their requirements and, as mentioned by Bonsiepe, cannot be solved from the rationality of quantification.

But even in such a controversial and inappropriate environment for technologies, Bonsiepe (1978) highlighted the impact of technology as well as its capacity to help in decision-making processes, while ensuring some degree of effectiveness. He stated that this does not deny the validity of a scientific approach to design, which, nevertheless, captures the nature of the design process best, freeing it from intuition and making it less personal. In others, it makes it more objective. Scientifically based designing aims, in part, to prevent nonsystematic performance and instead helps goals to be gradually achieved. It also serves to motivate design decisions, helping to explain why a project has reached certain solutions and not others.

Tool development

A tool was developed to analyze product development processes in SMEs by developing an epistemological concept of 'technique' and 'technology', using as basis the work conducted by Bonsiepe (1978) who states that the transfer and technological dependence between developed countries (metropolis) and developing countries (periphery) implies a certain disregard and degree of complexity not only when building autochthonous technological knowledge, but also when implementing certain dynamics in SMEs, which reinforces the need to design a site-specific strategy that corresponds to the context of periphery industry.

According to Bonsiepe (1978), developing countries embrace a multi-projected, not a self-projected approach, and this poor projection is perpetuated by university curricula for technical disciplines that usually give more importance to how technology is managed than how it is created, turning into a non-euphemism reflection of economic dependence: foreign textbooks, foreign educational purposes, foreign teaching methods—all linked to the needs and interests of the metropolis while notably overlooking local needs and interests.

The following were used as reference material to organize the study

Reports published by Colombia's Ministry of Commerce, Industry and Tourism in late 2008 that indicated that, at that time, 53,547 enterprises classified as SMEs existed in the country, of which 75.6% reported Trade and Services as their main economic activity and only 19.3% were involved with manufacturing activities. Because of the marked difference between production and marketing, it can be assumed that activities of the trade and services sector are based on legalizing patents and licenses and importing machinery and finished products. From another perspective, this difference suggests that there is a large market for finished products that could potentially be satisfied by national industries if the national manufacturing sector is strengthened (Ministerio de Comercio, Industria y Turismo, 2008).

• Benchmark studies conducted by Nicolini et al. (2007) and INTI on product development in SMEs, used as reference documents for Latin America.

• Problems identified by Colombia's Ministry of Commerce, Industry, and Tourism in relation to national micro, small, and medium enterprises (MSMEs) involved with manufacturing and referred to as the MSMEs program´s policy needs and strengths. Two of these problems are specifically addressed by this study: restricted access to technology and low capacity for innovation in research and development. Both are fundamental to the theoretical conceptualization of 'technique', 'technology', 'metropolis', and 'periphery' in a real context. (Ministerio de Comercio, Industria y Turismo, XXXX).

• Bonsiepe's experience in Chile and Gámez's in Colombia regarding technology transfer and technological dependence. It is therefore pertinent to venture toward the goal of transforming product development processes through technological dynamics.

The project's objective, however, was not to transform product development processes, but to specifically develop a tool to analyze the degree of application of technological dynamics in the development of already existing products. Subsequent phases of the project could involve making pertinent transformation. To fulfill this objective, the Product Development Assessment Matrix Applied to SMEs was developed. This tool serves to analyze the process of developing a structured product by simplifying the complexity of knowledge building by using the scientific method as backbone of technological development. Said simplification addresses economic opportunities, logistics, and technological capabilities of SMEs, empowering them to carry out minimal operations that delimit their processes within technology product development, specifically technology-based knowledge building.

Overall Matrix Structure

The matrix's backbone is based on the scientific method as primary anchorage of technological dynamics. It was built using a parallel between this method and the product development phases proposed by INTI in Argentina, complemented by certain elements of the proposal of Ulrich and Eppinger (2009) (see Table 1).

Table 1. Relationship between product development phases and scientific method components.

Phases	Product development	Scientific method component
Concept development	Definition of strategy Designing of concept Detailed design	Reconnaissance of facts Identification and formulation of problem Selection of pertinent factors Purpose of hypothesis formulation Mathematic translation Search for empirical and rational supportive data
Experimentation or testing	Verification and testing	Designing of test Test execution Preparation of results Inference of conclusions
Synthesis of results	Final statement	Comparison of conclusions Streamlining of model Suggestions for subsequent work

Source. The authors

This parallel allowed an initial comprehensive correlation to be established between product development phases and components of the scientific method. INTI's proposal included seven phases as follows: Definition of Strategy, Designing of Concept, Detailed Design, Verification and Testing, Production, Marketing, and Final Design. Two phases—Production and Marketing—were discarded as they were not considered indispensable for the purposes of this study. Three of the five remaining phases correspond to the stage of Concept Development, one to Experimentation and Testing, and one to Data Synthesis. Each phase consists of a series of operations across different technological levels and inevitable, in some cases, technical levels, which, in turn, have two types of elements that in most cases define whether they are technological or technical in nature: instruments (in the case of technologies) and tools (in the case of techniques).

Matrix components

Phases and operations form part of the five components of the matrix. Operations are divided, in turn, into technological and technical, and are defined by the tools or instruments they contain (see Figure 1).

		Instrument
	Technological operation	
		Instrument
PHASE		
		Tool
	Technical operation	
		Tool

Figure 1. Matrix components.
Source. The authors

Phases

Phases are the more general components of the matrix and correspond to a complete stage of product development. Phases contain multiple operations of any type, as well as different instruments or tools. Although they may contain certain technical elements, in this case they were considered entirely technological and their results are the outcome of operations performed within each phase.

The matrix consists of five phases, each with a specific objective:

- *Definition of Strategy*, which aims to identify key factors (users' needs) and then determine the relevance and significance of each factor to decide on the characteristics of the new product.

- *Designing of Concept*, which aims to select the ideal concept to develop, based on the analysis of feasibility, relevance, and user correlation by reviewing multiple alternatives.

- *Detailed Design*, which aims to define the physical, chemical, and color properties, among others, of the new product.

- *Verification and Testing*, which aims to corroborate, by testing, the compliance of requirements, determinants, and objectives established in previous phases.

- *Compilation of Experiences*, which aims to draw conclusions from the product development process by analyzing users' experiences in relation to the new product.

Types of phase

General performance parameters were established based on the operations and objectives of each phase. Three types of phases were identified and grouped, in turn, into stages:

- Sustentation or stage 1, which involves the establishment of product development guidelines. The name of this stage obeys its ability to endorse the decisions made in the following phases.

- Evaluation and selection or stage 2, which involves the development of multiple alternatives. Final selection is made after submitting each alternative to a series of filters to determine their feasibility and applicability.

- Internal and external assessment and verification or stages 3, 4, and 5, which aim to ensure that the product being developed meets previously defined requirements, determinants, and objectives. Phases 3 and 4 involve internal assessment and verification before the product is marketed, whereas phase 5 involves external assessment and verification and is based on the experiences of users acquiring the finished product.

Technological operations

The success in achieving the objectives of a given phase lies in the collection and processing of certain specific data within pertinent technological operations, which is then assigned one of five different scores depending on data collection methods, underlying rationale, control measures, and data synthesis and processing.

Eight factors were used as basis to assign the different values to any given operation. Technical operations have the same setup as technological operations, but they are ranked as 1 and 3 (Table 2).

Table 2. Determinants in assessing operations.

Determinant factor	Inferior levels		Intermediate level	Superior levels	
Refers to a creative process	Very low	Low			
Is based on technical operations		Low	Intermediate		
Produces raw data	Very low	Low	Intermediate*		
Operates with control instruments			Intermediate**	High	Very high
Is based on rational evidence			Intermediate**	High	Very high
Is based on other technological operations >=5				High	
Is based on other technological operations >=7					
Produces elaborated data			Intermediate*		Very high

* and ** indicate that one or the other may or may not occur without affecting operation development.

Operations are assigned scores of 1, 3, 5, 7, and 9, with 1 being Very Low and 9 Very High. This assessment helped determine the technological level of each operation. Performance was also assessed to determine how rigorously each operation was executed. In other words, a level-9 operation can receive a score of 1 if it does not comply with the conditions of that level.

Instruments and tools

As discussed in the conceptual development of technology and science, tools correspond to technical operations, whereas instruments correspond to technological operations, representing science.

Tools are less elaborate and correspond to actions lacking rational support but relatively effective in solving, for example, the unstructured problems mentioned by Bonsiepe (1978). Tools are also closely related to creative processes. Instruments, on the other hand, are developed based on technological components or rational evidence that endorse or condition the relevance of their application in specific stages as well as expected results.

These are the different components that structured the Product Development Assessment Matrix Applied to SMEs, from a general level to a specific level, as individual elements interlinked within the technological process.

The interaction between operations within each phase and between phases within the matrix is what enables the development of a technological product.

Matrix Diagramming

Matrix components converge in five tables corresponding to the five phases of product development. Each table indicates the operations involved, the tools or instruments defining each operation, the outcome of product implementation, and pertinent technological assessment.

Phase 1: Strategic definition. Technological know-how resulting from this phase was built by further developing the tools applied in initial operations until pertinent instruments to fulfill technological objectives were defined. This phase served to justify and link one phase to the immediately preceding phase. The initial phase served as basis to define the variables—based on user perception—most important in developing a new product, thus establishing the requirements for the following phase. Table 3 details Phase 1.

Table 3. Phase 1: Strategic Definition.

Operation	Technical operation of compiling data directly from users	Technical operation of compiling data indirectly from users	Technological operations of compiling data directly from users			Data synthesis
Tool or instrument	Client services Suggestion box Complaints and claims	Observations regarding product use	Interview	Focus group	Survey	Table on ranking of variables
Outcome	Suggestions made by clients	Relationships user-object, user-situation, extreme uses	Specific needs or uses	General needs or uses	Pertinence of needs and uses	Ranking of variables
Score	1	5	7**		9	9

Source. The authors

Phase 2: Designing and selection of concept. This phase was characterized by its technical content, reflected in four operations with scores less than or equal to 5. Unlike Phase 1, knowledge was built by justifying each higher-level operation based on a lower-level operation. The dynamics of Phase 2 involves evaluation and selection.

Therefore, a large number of technical operations occur during this phase because technological know-how has already been structured through high-level operations that involved evaluation and selection. These, however, did not interfere with defining objectives or justifying phase 2 outcomes. Table 4 details Phase 2.

Table 4. Phase 2: Designing and Selection of Concept.

	Purpose						
Operation	Generate ideas	Search for references	Filter concepts		Visualize and interact		Select and assess concept
Tool or instrument	Brainstorming	Consultation of patents	Benchmarking	Table on concept filtering	Sketch	Scale modeling	Table on concept evaluation
Outcome	Multiple alternatives	References to similar patented products	References to product development processes	Initial selection of alternatives	Represen-ta-tion	Ranking of variables	
Score	1	3	5	7		3	9

Source. The authors

Phase 3: Detailed design. This phase addresses scientific and parametric issues and therefore almost all of its operations are objective-driven and validated by rational evidence that defines them as technological.

In addition, verification tools such as CAD and physical appearance models were applied, which translate the adjustments identified during the phase to the product being developed, either virtually or physically. Table 5 details Phase 3.

Table 5. Phase 3: Detailed Design.

Operation	Definition of determinants		Manual parameterization	Computer-based refinement	Physical refinement
Tool or instrument	Consultation of normativities	Consultation of tables on ergonomics and anthropometric percentiles	Technical drawings	CAD software	Physical appearance models
Outcome	Legal determinants	Ergonomic and anthropometric determinants	Building plans and technical fact sheet of determinants	Identification of product adjustments	Identification of product adjustments
Score	7	7	5	5	5

Source. The authors

Phase 4: Verification and testing. This phase was defined as the highest level of technology assessment. Despite not having level-9 operations of data synthesis, the average score of operations of this phase are above 5, allowing it to be technologically defined. The phase involved evaluation and control. In other words, it verified that the decisions made throughout the process converge in the product being tested to ensure maximum or full correlation with established parameters. Because it is an operation of assessment and control, all instruments are defined based on rational evidence, preferably the outcome of previous operations or phases because this definition guarantees the objectivity of assessment results. Table 6 details Phase 4.

Table 6. Phase 4: Verification and Testing.

Operation	Virtual analysis		Physical analysis	Verification
Tool or instrument	CAD software	Prototype	Prototype	Observation of use
Outcome	Functional virtual analysis	Functional analysis	Verification of test determinants	Verification of test requirements
Score	5	5	7	5

Source. The authors

Phase 5: Compilation of experiences. The importance of this phase lies in that its outcomes determined the redesigning of the product and that it revealed critical points of development that need to be reconsidered. The product development process is cyclic so this phase must not only embrace the culmination of the current product development process, but also serve as starting point for a new product development process. Table 7 details Phase 5.

Table 7. Phase 5: Compilation of experiences.

Operation	Compiling technical experiences directly from users	Compiling technical experiences indirectly from users	Compiling technological experiences directly from users			Data synthesis
Tool or instrument	Client service Suggestion box Complaints and claims	Observation on use	Interview	Focus group	Survey	Table on ranking of shortcomings
Outcome	Users' suggestions	Successes and failures in compliance of requisites	Successes and failures in compliance of requisites	Successes and failures in compliance of requisites	Relevance of successes and failures in compliance of requisites	
Score	3	7	7		9	9

Source. The authors.

Conclusions

The conceptual development of technology as a form of knowledge building and development allowed certain elements to be identified, which, in the light of the apparent effectiveness of technical dynamics, are weakened or non-existent within the product development process. Clearly, it is not recommendable to say that techniques are undesirable when developing new products or modifying existing ones because even in the most advanced and successful technological processes, certain technical notions are necessary to achieve some of the objectives. Even so, it is not convenient and sometimes time-consuming and inefficient to leave all product development aspects to technical capabilities, or even worse, ignore them or replace them with a duplicate of another object.

On the contrary, the conception of new products within the technological framework promotes constant transformation and evolution, to the extent that knowledge is built around the process. Technology has this capacity because its dynamics are based not only on the rationale of each of the decisions made during product development (rational evidence), but also on the application of instruments that, as stated by Bonsiepe (1978), prevent non-systematic performance and provide resources and information needed to gradually achieve a specific objective.

Technology is therefore considered the means by which product development is optimized if partial and global results are constantly assessed and verified throughout the process, which also facilitates the redesigning and reformulation of concepts.

In practice, technology is present in every aspect of everyday life and brings to the table a broad range of considerations and implications in the case of product development. The number of variables being incorporated into technological dynamics at the industrial level is on the rise, and, to keep abreast, avant-garde developing countries are developing new strategies and processes. The metropolis establishes its own methodologies based on its own experiences and possibilities.

It is totally unreliable and inefficient to develop a technology based on a replica of proposals made by the metropolis. Therefore, technological knowledge building should be addressed within the product development process from the reality of the periphery, where the industrial context is currently defined by technical practices and technology transfer, evidenced in the decontextualization and duplication of foreign products. The context is structured based on numerous existing SMEs, whose potential cannot be compared in the least to the economic power, logistics, and infrastructure of large industries of developing countries.

The Product Development Assessment Matrix Applied to SMEs was developed based on this approach. This technological tool aimed to establish a series of product development phases, with their respective operations, together with a dynamic of constant evaluation and justification of decisions so the degree of technological knowledge building during the process can be easily determined, while also allowing the identification of those operations presenting shortcomings that could, at some point, lead to flawed development of a finished product.

The symbiosis between product development phases and scientific method components helped simplify both systems to their minimal elements, which guarantees technological knowledge building.

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