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Human Factors, Innovation and Technology, and Cluster Strategies as Triggers of New Product Development

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Abstract

This paper reports the results of a cross-sectional investigation into the organizational factors that influence the development of new products in Mexican organizations. We examine the degrees of complexity to determine the influence of three organizational levels, divided into four variables, on New Product Development (NPD) activities. The first level is related to Human Factors (HF), which focuses on the internal members involved in the NPD activities and their functions. The second level is related to Innovation (Inn) and Technology (Tec), which corresponds to the level of processes established in the organization and during NPD. The final level corresponds to the Cluster Strategies (QS) employed by the organizations, which focuses on their ability to work collaboratively with other organizations outside of their current internal boundaries. The influences of the proposed variables are then analyzed with results showing that QS, Inn, Tec, and HF explain, in a range of 58.8%, the emergence of successful NPD based on R^2. The study's findings provide a basis for future research through advanced statistical methods.

Keywords: Cluster strategies, technology and innovation, human factors, new product development.

1. Introduction

Engineering organizations are highly complex, involving large numbers of co-located and dispersed stakeholders (e.g., employees, contractors, suppliers etc.) with varying cultures, processes, and rules. New digital technologies, such as Artificial Intelligence (AI), Blockchain, social robots, and the Metaverse, are being embedded into NPD activities with the aim of providing enhanced automation and decision support for employees. Given this reality, further research is required to explore, from different perspectives, the digital transformation strategies, competitiveness, and automation opportunities arising from the use of technology, innovation, and human factors, which all impact upon the successful design and development of new products [1].

The relationship between humans and technology is growing and has a significant impact on the effectiveness of NPD teams [2]. For example, Intelligent Decision Support Systems (IDSS) are now being used to support decision-making in engineering design, while social robots can be used to support knowledge creation and the capturing of lessons learned during NPD. In such complex environments, the leadership style of managers and the level of team commitment are also seen as crucial for enabling creativity during the development of new products [3].

Considering that NPD involves a high level of complexity with multiple stakeholders contributing to its success, this study proposes a theoretical model that balances different levels of analysis or "complexity". We consider that the goal of NPD is the creation of new innovative products to meet the needs, wants, and desires of consumers in a target market(s). In this paper, we analyze the effects of four independent variables, from three organizational levels, on the NPD process to expand our understanding and knowledge of successful NPD efforts. The first level relates to human factors [1st level of complexity],

while the second relates to innovation and technology [2nd level of complexity]. Finally, the ability of the organization to collaborate with others in the sector is explored through their clustering strategies [3rd level of analysis][4]. Figure 1 shows the theoretical model proposed in our study where the context is the development of new products.

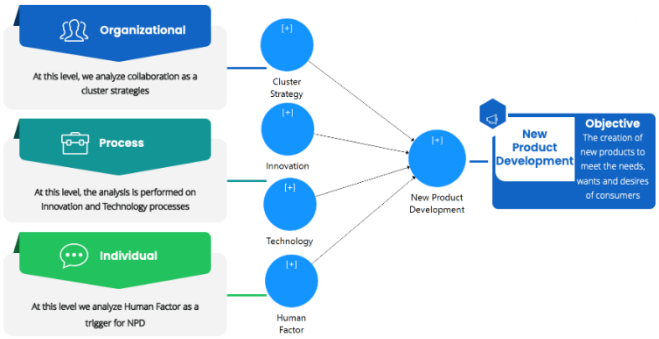

Figure 1. Proposed theoretical model

At the Organizational level, we identify cluster strategies which refer to the actions taken when organizations are encouraged to increase their competitive capabilities by sharing internal skills and knowledge with other organizations. This activity creates an economic cluster and provides advantages as opposed to when competing alone, mainly because knowledge is shared among other stakeholders in the ecosystem, thereby increasing the capabilities of all the organizations involved. This associativity increases the potential for creativity and depends on the approach to organizational governance [5].

The second (i.e., innovation) and third (i.e., technology) factors, both at the Process level, act as triggers in new product development and are vital for all planned activities [6]. Both are promoted to improve the creativity of employees in the workplace and, if properly managed, work as one of the most highly desirable lines of action [7]. Innovation contains, by its very nature, an approach to designing new products based on creativity. It combines methods and procedures whose disruptive characteristics promote collective intelligence.

Finally, at the Individual level, human factors are identified as a necessary part of NPD. This factor is recognized as a desirable characteristic by engineering teams [8]. In this vein, it is necessary to establish how collaboration networks are formed, both internally and externally, and how these can be improved. These are considered to be the natural trigger for the creativity required to boost organizations' competitiveness and their successes in new product development.

2. Literature review

2.1. New Product Development

The design and development of new products present numerous technological, process, and people management challenges [9]. For this reason, the study of NPD can be achieved in a holistic way with an emphasis on complexity [10]. Complexity requires creativity and the initiative of individuals to build competitive dynamics and internal policies that promote organizational practices [11]. Although different approaches exist, the creativity needed for successful NPD is only sometimes achieved by organizations [12], [13]. The causes of NPD failure [14], [15] and success [16], [17] have been characterized as various elements related to e.g., marketing, innovation, and technology, in addition to other factors that give it complexity [9]. Table 1 lists some of the causes of the success and failure in the search for NPD.

Table 1. Success and Failure of NPD.

Environment	Success	Failure
External	New market definitions Market recognition	Underestimate competence and market position Overestimate demand Setting selling costs fail
Internal	A technical opportunity Internal R&D management Venture decisions Development funds Technical entrepreneur	Technical issues Unsuccessful capabilities Funding inability Unable to spread the business vision

As shown in Table 1, the conditions for NPD success and failure can be both internal and external. With regard to external factors, it is crucial that organizations have a sound understanding of the market, including the demands, wants, and desires of consumers who occupy the space. These perspectives allow us to observe how the NPD concept has comprehensive and holistic approaches to its understanding. This position resembles the paradigm of complex systems, which in turn facilitates the recognition of the high variability involved in each process. This variability makes the study of NPD more complex and allows researchers to determine the relevance of this theoretical approach to the study process.

Given the growth in marketplace competition, it is essential that organizations possess the ability to capture new ways of generating and analyzing creative processes when developing new products. Extant literature reports the importance of organizations continuously improving their creative culture [8]. With such actions, the generation of new technological products based on knowledge must have the right environment for their development. Organizations that compete in a common market usually implement mechanisms that facilitate the development and creation of organizational structures at different levels of analysis.

2.2. Cluster strategies

Organizations that actively participate in clustering or the development of innovation ecosystems can create a competitive advantage over their competitors [18]. Each economic sector or geographical region possesses unique characteristics which, if jointly taken advantage of, can create shared rewards [19]. The strategies that organizations use to determine when to locate themselves in clusters and access opportunities contain many factors that are part of the systemic competitiveness approach. This approach requires the grouping and sharing of skills and abilities where the intention is to generate shared values [20].

Only some organizations take the risk of helping their potential competitors by contributing with strategic factors that usually become collaborative advantages that drive differentiation from competitors. In general, organizations

operating in specific regions consider regional grouping as a determinant of industrial location and economic growth, but not as a public policy variable for business incentives or with the idea of improving the business climate. The location of clusters is unequivocally the only factor that stands out in recent empirical studies, especially in terms of location issues that combine efforts and respond to more specialized requirements demanding attention in the market [21]. Faced with increasing competition, an organization's ability to acquire knowledge from other regions has become essential for the development of new products. Existing research emphasizes how organizations should practice Social Product Development (SPD), allowing for the inclusion of all stakeholders in the generation, selection, validation, and commercialization of ideas [22]. The cluster strategy, therefore, becomes an activity that enhances the creative and collaborative environment for triggering the creation of new products. This study, therefore, proposes the following hypothesis:

H_1: Cluster strategies positively and significantly influence the development of new products.

2.3. Innovation

Innovation and creativity are required to achieve effective design and development of new products. Organizations must also focus on the processes and strategies used by their leaders to commercialize products using new technologies. In the process of continuous improvement, organizations seek to commercialize new technologies, creating significant changes and value in new or existing markets. The variable economic approach uses different strategies for marketing and innovation to increase the impact of creativity, while innovation in customer understanding allows organizations to interpret changes in consumers' unmet needs more effectively. This makes it easier to develop new actions to address consumers' needs through offers from market entry to growth [23].

Organizations can also use the "jobs to be done" framework to identify opportunities that create value for customers, which largely brings about the establishment of ecosystems in networked markets. The role of innovation, as an element of analysis at the process level, is complemented by others to influence NPD. This relationship between constructs helps in understanding the creative phenomenon that innovators require as a trigger for NPD. In this regard, this study proposes the following hypothesis:

H_2: Innovation positively and significantly influences the development of new products.

2.4. Technology

Organizations must maintain their competitive advantage in the market if they want to achieve long-term survival. To achieve this, many organizations use product families and product development based on technological platforms to increase the variety of product offerings that can satisfy demand, shorten delivery times, and reduce costs. Extant research on new product development focuses on a market-driven approach that targets cost savings in pursuit of profit and market share. One of the approaches used in NPD is the technology road mapping strategy which allows organizations and NPD teams to plan their market entry for new products, which is considered at the process level [19], [24]. Thus, this study proposes the following hypothesis:

H_3: Technology positively and significantly influences the development of new products.

2.5. Human factors

Product innovation refers to the introduction of new designs, technologies, or components, that support an organization's products. This definition is associated with the definition of new product development. In this phenomenon, successful product innovation depends on the acquisition and combination of knowledge, which in turn explains how employees access each other's knowledge, connect knowledge components, and recombine elements that were previously unrelated [25]. Consequently, employees play a fundamental role in innovation because they participate in the processes of acquiring and combining knowledge [26]. Thus, human capital, defined as the knowledge, skills, and abilities embedded in employees and operationalized as the percentage of highly educated employees in an organization, is an important driver of NPD. Therefore, this study proposes the following hypothesis [27]:

H_4: Human factors positively and significantly influence the development of new products.

3. Methods

This paper reports on a cross-sectional study where the design was non-experimental since the study's variables were not modified but analyzed according to their nature without affecting their structure. The scope of the research is correlational between the independent and dependent variables. However, this nature is limited to the number of variables considered in the proposed model, as illustrated in Figure 1.

The population considered in this study was 752,000 employees in the IT sector in México [28]. The study's sample was selected using a non-probabilistic approach consisting of 384 valid responses. Individuals were selected based on their location, ease of access, and through a selection of relevant companies obtained through information provided by the commercial and technical chambers of commerce. To solicit responses to the questionnaire, which could be completed either online or in-person, the authors used e-mails, social network posts, and onsite visits. The questionnaire took approximately 20 to 30 minutes to complete. All respondents were Mexican IT workers from middle and lower management who voluntarily agreed to complete the questionnaire with items related to the study, i.e., NPD, QS, Inn, Tec, and HF. Survey responses were collected from July to October 2022.

The research instrument consisted of positive affirmative statements relating to the respondent's perceptions, while response options comprised 7 points on a Likert scale. 9 items were assigned to the dependent variable of NPD, while 3 items were assigned to each independent variable (i.e., QS, Inn, Tec, and HF). The former was aimed at the individual analysis of the proposed variables and the verification of fundamental aspects, such as the mean, modes, standard deviations, variance, and

levels of asymmetry and kurtosis, i.e., the assessments that made it possible to determine the internal consistency of each of the items that make up the constructs. Additionally, the instrument's reliability was tested on each variable. Univariate and multivariate analysis techniques were used in this research. The multivariate analysis techniques employed were multiple linear regression analysis.

4. Results

4.1. Reliability analysis

Table 2 shows that when the results of the reliability analysis were identified, high Cronbach's Alpha indices were obtained, indicating that the instrument's reliability was significant. Also, the relationship between the factors and Cronbach's Alpha indicated that the instrument has significant content validity.

Table 2. Reliability analysis.

Variable	Cronbach's alpha	rho_A	Composite Reliability	AVE
NPD	0.881	0.890	0.904	0.515
QS	0.827	0.832	0.897	0.743
HF	0.837	0.839	0.902	0.754
Inn	0.752	0.770	0.857	0.667
Tec	0.830	0.832	0.898	0.746

According to Nunally [29], Cronbach's Alpha values between 0.6 and 0.7 are acceptable for items that form a single construct in social sciences. The results of 0.881 for NPD, 0.827 for QS, 0.837 for HF, 0.752 for Inn, and 0.830 for Tec, show a high internal consistency for each variable. The levels confirm this in rho A, composite reliability, and AVE values.

4.2. Correlation analysis

Table 3 shows a high correlation between NPD and QS ($r = 0.713$ and $p < 0.010$), Inn ($r = 0.705$ and $p < 0.010$), Tec ($r = 0.638$ and $p < 0.010$), and HF(0.586 and $p < 0.010$). These data are under the Pearson method. Similarly, when Spearman's correlation analysis is performed, we find NPD and QS ($rho = 0.705$ and $p < 0.010$), Inn ($rho = 0.660$ and $p < 0.010$), Tec ($rho = 0.656$ and $p < 0.010$), and HF (0.587 and $p < 0.010$). Therefore, both methods confirm the same results and accept the research hypotheses. It is important to clarify that this interpretation does not imply causality. The results imply that when one of the variables is present, such as QS, Inn, Tec, or HF, NPD is modified somehow, and the positive relationship between them is maintained.

Table 3. Correlation analysis.

	Method	QS	Inn	Tec	HF
NPD	Pearson	0.713**	0.656**	0.638**	0.589**
	Sig. (2-tailed)	0.001	0.000	0.001	0.001
	Spearman's Rho	0.705**	0.660**	0.656**	0.587**
	Sig. (2-tailed)	0.002	0.000	0.002	0.002

** Correlation is significant at the 0.01 level (2-tailed).

4.3. Regression analysis

The value of (R Square), presented in Table 4, indicates that a high explanatory reference of the statistical model is observed. This is because the four variables studied explain 58.8% of the phenomenon. Given this exercise, the model's applicability is adequate and helps confirm the hypotheses.

Table 4. Model summary.

Model	R	R square	Adjusted Square	Std error in the Estimate
1	0.767	0.588	0.584	0.73204

a. Predictors: (Constant). QS, Inn, Tec, HF

Table 5 shows that the (Constant) and independent variables (i.e., QS, Inn, Tec, and HF) have a highly significant value in the incidence of the dependent variable (i.e., NPD) and form the algebraic expression shown in Equation 1. This also validates acceptable VIF values to confirm low collinearity.

Table 5. Regression model coefficients.

Model	UnStd Coeff.		Std Coeff	t	Sig	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VF
(Constant)	.844	.213		3.970	.000		
QC	.353	.051	.384	6.956	.000	.405	2.471
Inn	.168	.055	.174	3.075	.002	.384	2.605
Tec	.129	.052	.137	2.483	.014	.404	2.477
HF	.173	.042	.190	4.156	.000	.589	1.698

a. Dependent variable: NPD

Equation 1. Regression Model

$$NPD = 0.844 + 0.353\,QS + 0.168\,Inn + 0.129\,Tec + 0.173\,HF$$

It is also revealed in Equation 1 that the element that most influences NPD is the QS variable. This confirms an important trend towards collaborative strategies, and the ability of organizations to integrate interdisciplinary teams from different organizations to influence the creation of new products and value propositions. Similarly, the second relevant value is that of the HF variable, which lies primarily in the trained and qualified people who are part of the organization and who, according to the findings, are responsible for NPD presence.

5. Conclusion

This study unites variables of different levels of complexity under an umbrella that explores the development of new products. From a holistic perspective, we list a series of theoretical approaches that make up a proposal for a growing line of research that seeks to promote the formation of interdisciplinary and intraorganizational teams. The study of this phenomenon has differentiated edges between technology and human factors. The latter identifies soft aspects, such as creativity, cognitive diversity, and collaborative work as required elements for NPD to be a natural consequence of their organizational activities. In the first case, the highest level of complexity is the QS variable. This demonstrates the

importance of collaborative working and the association between organizations in managing engineering design teams to meet their objectives of creating new value propositions. These proposals form part of improving the competitive processes of each of the associated organizations to create new products and are thus one of the strategies that open up internal processes to add skills and capabilities between different organizations [30].

However, at the intermediate level of complexity, where the Inn and Tec variables are found, it is observed that they have discrete importance and are less than HF, which is the variable with the lowest level of complexity. This reveals the importance of people in all organizations where people are responsible for developing a culture that supports and strengthens the processes that are part of the Inn and Tec variables of the organization.

5.1. Contributions

The results of this study demonstrate that management can intervene in configuring all variables to increase NPD. In complex organizations, the people who are represented as HF and who support the variables of Inn and Tec intermediate processes require constant and adequate attention to increase the effects on NPD. By applying the quantitative methodology and responding to the statistical characterization, it is shown that the tests carried out confirm that the four hypotheses are correct. This means that QS, Inn, Tec, and HF do, indeed, have a positive and statistically representative influence on the dependent variable, NPD. Accordingly, contributions to the understanding of management practices in NPD should consider these factors and a new set of skills should be developed for complexity leadership [31].

5.2. Limitations and future work

This study proves the importance of analyzing NPD from a multiple-perspective focus. In this paper, we validate the importance and relevance of the proposed initial variables. The main limitation of this research is the application of the research instrument. Therefore, the generalizability of our study is not demonstrated. In future work, to extend the validity of the research, we will continue to apply the questionnaire to other industrial sectors and technological profiles. We call for applications of our proposed methodology in other organizations. We consider that its applicability is adequate for other economic and industrial sectors with NPD programs. Consequently, future studies should collect data from other technology-based firms and apply advanced statistical methods, such as partial least squares, to validate the proposed model.

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