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ORIGINAL

Management indicators for microenterprises based on the theory of complex adaptive systems

Indicadores de gestión para las microempresas basado en la teoría de sistemas complejos adaptativos

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ABSTRACT

Introduction: microenterprises constitute the foundation of the business fabric in emerging contexts, contributing to employment and economic growth; however, they face limitations in financing, management, and competitiveness that affect their sustainability.
Objective: to determine the influence of interactions with customers, suppliers, competitors, and regulators on the achievement of management objectives in microenterprises.
Method: an applied, quantitative, non-experimental, and cross-sectional study was conducted. The sample consisted of 153 microenterprises probabilistically selected from a population of 251 affiliated with the San Martín Chamber of Commerce. A questionnaire with 30 indicators distributed across five constructs was applied, with reliability verified through Cronbach's Alpha and McDonald's Omega. The model was evaluated using structural equation modeling with the WLSMV estimator.
Results: the model showed adequate fit indices ($x^2/df = 1,07$; RMSEA = 0,019; CFI = 0,992). Only interactions with customers had a significant influence on management objectives ($p = 0,001$), while suppliers, competitors, and regulators showed no significant effects ($p > 0,05$).
Conclusions: customer-centered management is the main determinant of microenterprise success. The proposed framework provides practical tools to strengthen competitiveness and sustainability.

Keywords: Microenterprises; Management Indicators; Complex Adaptive Systems; Competitiveness.

RESUMEN

Introducción: las microempresas constituyen la base del tejido empresarial en contextos emergentes, aportando al empleo y al crecimiento económico; sin embargo, enfrentan limitaciones en financiamiento, gestión y competitividad que afectan su sostenibilidad.
Objetivo: determinar la influencia de las interacciones con clientes, proveedores, competidores y reguladores en el cumplimiento de los objetivos de gestión en microempresas.
Método: se desarrolló un estudio aplicado, cuantitativo, con diseño no experimental y transversal. La muestra fue de 153 microempresas seleccionadas probabilísticamente de una población de 251 afiliadas a la Cámara de Comercio de San Martín. se aplicó un cuestionario con 30 indicadores en cinco constructos, verificándose la confiabilidad mediante Alfa de Cronbach y Omega de McDonald. El modelo fue evaluado mediante ecuaciones estructurales con el estimador WLSMV.

Resultados: el modelo presentó índices de ajuste adecuados (x^2/df = 1,07; RMSEA = 0,019; CFI = 0,992). Solo las interacciones con los clientes influyeron significativamente en los objetivos de gestión (p = 0,001), mientras que proveedores, competidores y reguladores no mostraron efectos significativos (p > 0,05). **Conclusiones:** la gestión centrada en clientes es el principal determinante del éxito de las microempresas. El marco propuesto ofrece herramientas prácticas para fortalecer la competitividad y la sostenibilidad.

Palabras clave: Microempresas; Indicadores de Gestión; Sistemas Complejos Adaptativos; Competitividad.

INTRODUCTION

Management indicators have become key tools for measuring organizational performance, as they allow for the evaluation of processes, results, and levels of efficiency in decision-making.[1,2,3] Their application is especially relevant in the field of microenterprises, where the availability of reliable information can mean the difference between business continuity and failure. However, traditional indicator models focus on financial and operational variables, without sufficiently incorporating the complexity of the dynamic environments in which these organizations operate.[4,5]

In this context, complex adaptive systems theory provides a relevant approach for the study of companies. This theory conceives of organizations as open systems, composed of multiple agents that interact, adapt, and evolve in response to their environment.[6] From this perspective, management results do not depend solely on internal factors, but also on the quality of interactions with customers, suppliers, competitors, and regulators, which are considered subsystems that determine overall performance.[7,8]

Microenterprises, also known as MYPEs, represent a fundamental segment of the business fabric in developing countries, as they generate employment, boost the local economy, and contribute to social welfare.[9,10] However, their small size and limited resources condition their access to financing, technological innovation, and specialized human capital, which hinders their sustainability in highly competitive markets.[11,12,13]

The situation is exacerbated by the financial barriers faced by microentrepreneurs, such as lack of credit history and the perception of risk by banking institutions, which restricts their capacity for investment and growth.[14,15] Added to this are insufficient training in business management and informality, factors that limit the implementation of data-driven strategies and reduce their ability to adapt to changes in the environment.[16,17]

The COVID-19 pandemic intensified these difficulties, causing drops in demand, disruptions in supply chains, and the permanent closure of thousands of microenterprises. In Peru, more than 135 000 MYPEs ceased operations between 2020 and 2022, while the informality rate exceeded 80 %, particularly affecting the commerce, tourism, and services sectors. This crisis highlighted the urgent need for more robust measurement systems that support resilience and strategic decision-making in these types of organizations.

In this context, it is clear that traditional management indicators are insufficient to capture the complexity of microenterprises. Their emphasis on static metrics overlooks dynamic interactions with actors in the environment, limiting the generation of strategic information for sustainability and competitiveness. An alternative approach is therefore needed that recognizes the adaptive and systemic nature of these organizations.

The integration of management indicators with complex adaptive systems theory offers an innovative framework for evaluating the performance of microenterprises. This approach allows for the design of metrics that not only measure internal results but also consider how interactions with customers, suppliers, competitors, and regulators influence the achievement of management objectives. Under this logic, the aim is to provide a model that strengthens adaptability, improves competitiveness, and promotes sustainability in scenarios of uncertainty and high competition.

METHOD

Scope of study

The study was conducted in the district of Tarapoto, located in the province of San Martín, in the northeastern region of Peru. This territory, characterized by its Amazonian environment and dynamic commercial activity, was selected due to the significant concentration of commercial microenterprises that make up the local business fabric.[20,21] The implementation period ran from April 2024 to February 2025, which allowed for the collection of representative information in a post-pandemic scenario, key to analyzing the resilience and adaptability of the business units evaluated.

Research design

A non-experimental, applied, quantitative design was adopted, developed using a cross-sectional approach that allowed information to be collected at a single point in time. The research reached an explanatory level, as it sought to analyze the causal relationships between the interactions of micro-enterprises—conceived as complex adaptive systems—and the achievement of their management objectives.

Population and sample

The population consisted of micro-enterprises in the district of Tarapoto associated with the San Martín Chamber of Commerce, Production, and Tourism, totaling 251 organizations registered as of March 2024, of which 27 are in the construction and related sectors, 74 in commerce, 25 in export, 79 in services and production, and 46 in tourism. To select the sample, a simple random probability sample was applied to a finite population at a 95 % confidence level, resulting in a total of 153 microenterprises.

Procedure

The data collection instrument was designed based on the theoretical model of complex adaptive systems proposed by Díaz Rios et al.[22], which considers the interaction of microenterprises with suppliers, customers, competitors, and regulators as subsystems that determine organizational performance (figure 1). The questionnaire included a total of 30 indicators distributed across five constructs (interactions with suppliers, customers, competitors, regulators, and management objectives), which were operationalized in items measured using a five-point Likert ordinal scale. For transparency and replicability purposes, the questionnaire can be requested from the corresponding author.

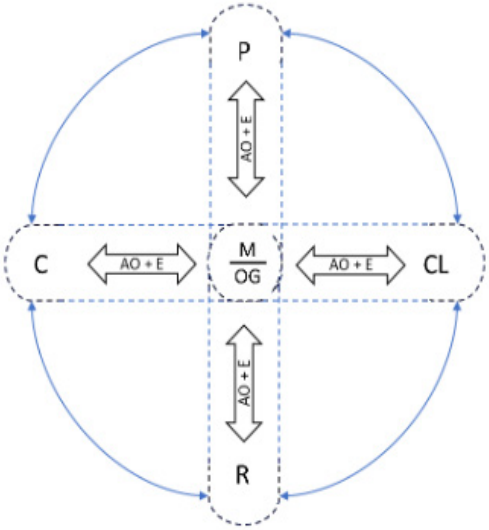

Figure 1. Conceptual model of the commercial SME as an SCA. M: SME; MG: management objectives; S: suppliers; C: customers; R: regulators; C: competitors; SO: self-organization; E: emergence[22]

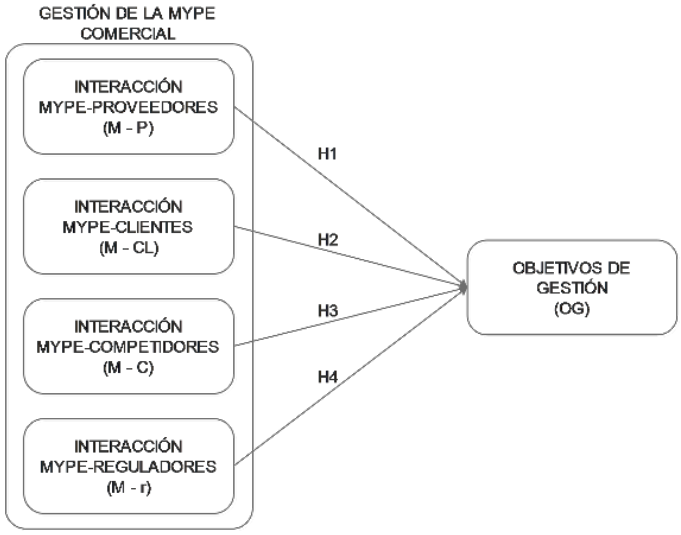

Figure 2. Theoretical model of MSME management

The theoretical model for managing micro and small enterprises consists of four independent constructs: micro and small enterprise–supplier interaction (M–P), micro and small enterprise–customer interaction (M–CL), micro and small enterprise–competitor interaction (M–C), and micro and small enterprise–regulator interaction (M–R), which represent the strategic links that influence business management. Each of these constructs was

proposed as a predictor variable for management objectives (MO), understood as the expected result in terms of efficiency, competitiveness, and sustainability of the microenterprise. Based on this approach, four research hypotheses were formulated:

H1: interaction with suppliers significantly influences management objectives.
H2: interaction with customers significantly influences management objectives.
H3: interaction with competitors significantly influences management objectives.
H4: interaction with regulators significantly influences management objectives.

First, the reliability of the constructs was verified using Cronbach's alpha and McDonald's omega (table 1). The proposed structural model was then validated using Structural Equation Modeling (SEM) under the WLSMV (Weighted Least Squares Mean and Variance Adjusted) estimator, which is appropriate for categorical variables measured with ordinal scales and relatively small samples.

Table 1. Reliability of the constructs of the MYPEs management model

Construct	Cronbach's Alpha	McDonald's Omega
MSME-supplier interaction (mp)	0,80	0,87
SME-customer interaction (mcl)	0,78	0,85
SME-competitor interaction (mc)	0,7	0,79
Interaction between SMEs and regulators (mp)	0,7	0,78
MSME management objectives	0,84	0,85

Ethical aspects

Informed consent was requested from all participants, who voluntarily agreed to respond to the questionnaire, ensuring their right to decide and to withdraw at any time. The confidentiality of the information was guaranteed through anonymity in the tabulation and reporting of the data. Likewise, the principle of beneficence was respected, seeking to maximize the contributions of the research to the strengthening of microenterprise management; and the principle of justice, ensuring the equitable inclusion of participants based on the diversity of the sector.

RESULTS

After processing the data using structural equations, it was found that the proposed model has the following fit indices: x2 = 423,365 (df=395; 0<;x2≤ 2df); x2/df=1.07 (0 ≤ x2 /df ≤ 2); RMSEA=0,019 (0 ≤ RMSEA ≤ 0,05); SRMR=0,081 (0,05<;SRMR ≤ 0,100); CFI=0,992 (0,97 ≤ CFI ≤ 1,00); GFI=0,935 (0,90 ≤ GFI ≤ 0,95); AGFI=0,923 (0,90 ≤ AGFI ≤ 1,00; close to GFI); which, as proposed by Schermelleh-Engel et al.[23] , show that the proposed management model is acceptable.

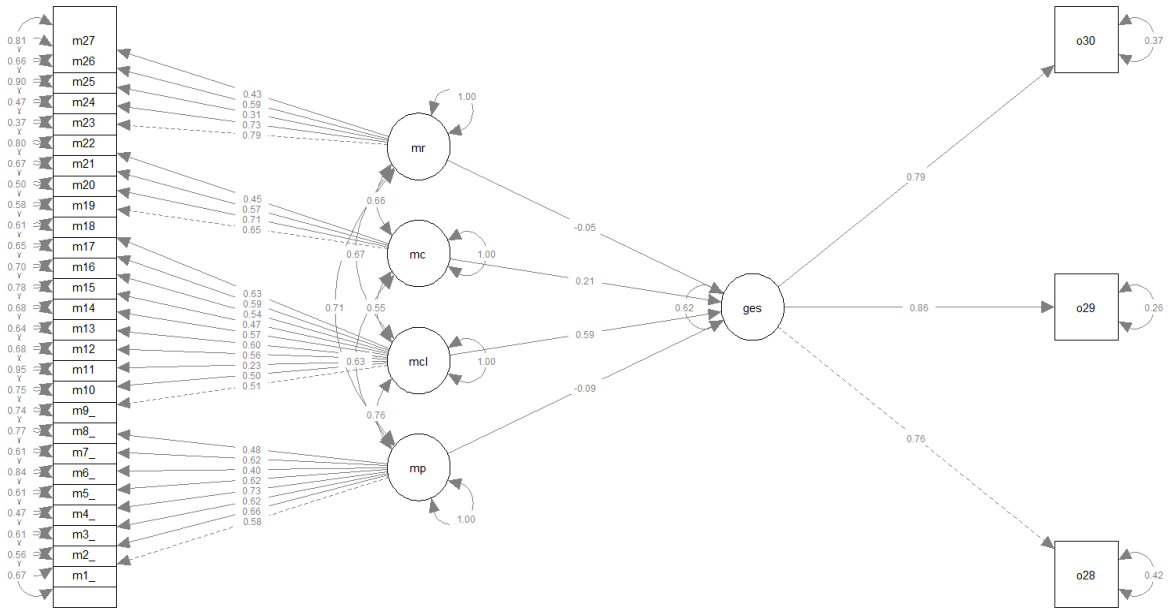

Figure 3. Path diagram of the management model for commercial microenterprises in the district of Tarapoto

The validation of the proposed model for the reality of commercial MYPEs in the district of Tarapoto establishes that the measurement of interactions and their influences will allow the hypotheses established by the model to be tested, as shown in figure 3.

The results of processing the data using structural equations have determined that of the four hypotheses, three have been rejected and one has been accepted. The rejected hypotheses are the interaction of the MSME with suppliers and its influence on management objectives; the influence of the interaction of competitors with the MSME on management objectives; and the influence of the MSME's interactions with regulators on management objectives. The hypothesis that was accepted is the influence of SME interactions with their customers on management objectives. These results can be seen in table 2.

Table 2. Reliability of the constructs of the MSME management model

Hypothesis	Estimate	Std. Err	P (> | z |)	Std. lv
MP→ GES	-0,079	0,138	0,569	-0,088
MCL→ GES	0,793	0,244	0,001	0,589
MC→ GES	0,189	0,121	0,119	0,208
MR→ GES	-0,046	0,133	0,731	-0,054

Note: MP: MSME-Supplier Interaction, MCL: MSME-Customer Interaction, MC: MSME-Competitor Interaction, MR: MSME-Regulator Interaction, GES: Commercial MSME Management Objectives

However, strong and statistically significant positive covariances have been found between MSME-customer interactions and the other interactions in the model, which highlights the relevance of the influence of MSME-customer interactions in achieving MSME management objectives, as shown in table 3 below.

Table 3. Covariances - covariate indicators

Indicator (covariance)	Factor loading	P(>|z|)
mcl <--> mp: Impact of suppliers on customers	0,757	0,000
mcl <--> mc: Impact of competitors on customers	0,552	0,000
mcl <--> mr: Impact of regulators on customers	0,671	0,000

Note: mp: microenterprise-supplier interactions, mcl: microenterprise-customer interactions, mc: microenterprise-competitor interactions, mr: microenterprise-regulator interactions

These covariances represent strong relationships between SME interactions that can provide evidence on indicators that will help with information for better decision-making to achieve SME objectives. Considering the results of the structural equations, it has been determined that the interaction between micro and small enterprises and their customers is the fundamental interaction that explains, in the case studied, the achievement of the management objectives of commercial microenterprises. Based on this interaction and the related covariances, a series of indicators have been determined that will help gather information for better decision-making by microentrepreneurs and thus improve the probability of survival in a competitive market.

DISCUSSION

Product-related management indicators proved to be of fundamental importance in improving the operational efficiency and competitiveness of commercial microenterprises. These indicators make it possible to identify strengths and weaknesses in operations and facilitate benchmarking against competitors. This finding coincides with previous studies which highlight how microenterprises, operating in a highly competitive environment, must rely on product-related metrics to sustain their market share.

The use of process-oriented indicators proved to be an effective practice for monitoring progress toward long-term strategic objectives. This study found that alignment with business goals is achieved when monitoring is combined with information systems adapted to the scale of the microenterprise.[26] This coincides with research that highlights the need for information tools tailored to the characteristics of MSMEs, which allow indicators to be exploited more effectively and improve decision-making.[27]

With regard to information exchange, the results show that indicators related to the interaction of microentrepreneurs with their immediate environment are crucial for sustainability. This finding is consistent with [26],which points to the importance of stakeholder relationships for operational efficiency and strategic planning. However, unlike other studies where interaction with suppliers is often decisive, in this research it was customers who had the greatest influence on management objectives, revealing a particular feature of the context analyzed.

In the operational sphere, indicators are consolidated as tools that allow for the organization of dispersed information, monitoring of staff turnover, and evaluation of consumer satisfaction.[28] This result is in line with the proposal by [29] that recommends the use of KPIs as a way to standardize processes, reduce costs, and strengthen business management. The convergence of findings reinforces that indicators not only play a control role but also contribute to the sustainability of microenterprises in highly competitive environments.[30]

The methodology applied, based on structural equation models under the WLSMV estimator, was justified by the ordinal nature of the variables and the sample size, which is consistent with recent research in similar contexts. This approach allowed us to empirically test the hypotheses and demonstrate the applicability of complex adaptive systems theory, which conceives microenterprises as interdependent systems whose management depends on the quality of their interactions with the environment.

Taking into account the previous results, three types of indicators have been established based on the measurement of the variables:

Product indicators

- Product offering to customers.
- Product order and location.

Information exchange indicators

- Customer service.
- Customer needs.
- Customer suggestions.
- Customer information.

Operational indicators

- Low-price sales.
- Product access.
- Order to serve.
- Service and quality.

Product indicators

Stock Depletion Rate (SDR)

This indicator measures how often products requested by microenterprise customers are unavailable in the small business's inventory, allowing for prioritization of supply. Indirectly, this indicator can provide information on the amount of sales being lost or the profit not being earned.

The data required to measure the Stock Out Rate (SOR) can be obtained from a manual record or a basic inventory record of how many times customers ask for a product that is not in stock. The number of requests for unavailable products is compared to all product requests made during a given period. High values could indicate a need to improve the small commercial enterprise's merchandise supply criteria.

TAS=(Number of times a requested product is not available)/(Total number of product requests) x 100

Price Complaint Rate (PCR)

The price complaint rate indicator seeks to determine customer dissatisfaction with prices. High values for this indicator could indicate the need to establish new parameters or criteria for price allocation.

To measure this indicator, customer complaints regarding product prices must be recorded manually or using a basic system, using the total number of customer interactions (sales, inquiries, etc.) as a reference.

TQP= (Number of complaints related to price)/(Total customer interactions) x 100

Product Reorganization Rate (TRP)

The order and presentation of products in a commercial business influence the customer experience, facilitate purchasing, and therefore influence sales. Thus, when products for sale are kept in order, they help optimize inventory and operational efficiency.

To measure the TRP indicator, it is necessary to keep track of the number of times products need to be reorganized because they are not in the right place. A product is not in the right place when it is misplaced, out of order, or outside its designated location. High values for this indicator allow you to identify disorganization problems and take measures to maintain the order of products for sale in the establishment.

TRP=("(Number of times @products are rearranged in a period of time))/(Total days evaluated) x 100

Information exchange indicators

Positive Interaction Rate (PIR)

Friendly and cordial service is an essential element of customer satisfaction and loyalty in a small commercial business. Evaluating this factor makes it easier to identify areas for improvement in customer interaction and ensures that all customers receive high-quality service.

This indicator measures how often a customer is treated in a friendly and courteous manner. This information will enable decisions to be made to improve customer satisfaction and increase the likelihood of future repurchases, as well as influencing customer loyalty.

To measure this indicator, it is necessary to record interactions between staff and customers that are considered positive (friendly greetings, smiles, pleasant tone of voice, and any positive interaction with customers). This can be done through direct observation or by recording customer interactions by contact staff.

TIP=(Number of Positive Interactions Recorded)/(Total customer interactions) x 100

Accurate Recommendation Rate (ARR)

Knowing customer needs is an important factor in offering personalized service and anticipating their expectations in a commercial microenterprise, thereby establishing differentiated conditions in the customer experience and customer loyalty.

To measure this indicator, it is necessary to record the frequency with which microenterprise staff recommend products to customers without being asked and also to record the number of times that recommendations made result in a purchase.

Having the data for this indicator reveals the ability of the microenterprise and sales staff to identify customer needs and offer the right products to meet those needs.

TRA= (Number of product recommendations@ accepted by the customer)/(Total recommendations made) x 100

Suggestion Implementation Rate (SIR)

It is crucial to accept customer recommendations in order to optimize the service and customer experience of a commercial microenterprise. Not only does listening to and acting on customer recommendations increase satisfaction, but it can also produce useful ideas for improving the business.

The SIS measures the ability of the business, and specifically the decision-makers of the microenterprise, to act on customer suggestions, which can improve loyalty and satisfaction.

To measure this indicator, a record must be kept of customer suggestions, which are obtained through comments, person-to-person interactions, social media, or any other means of contact. In addition, it is necessary to quantify how many of the suggestions are implemented or serve as a basis for improving the business within a given time frame.

TIS= (Number of suggestions implemented)/(Total suggestions received) x 100

Informed Purchase Rate (IPR)

Providing customers with information so they can make informed decisions about the products they buy from a microbusiness is essential. A customer who has sufficient information will make a good purchasing decision and will not only be happier with their purchase, but also more likely to return and recommend your business.

The Informed Purchase Rate (IPR) indicator requires recording how many times customers make a purchase after staff provide them with detailed information about the products, in addition to recording the number of purchases made. This indicator can be used to measure the effectiveness of the information provided in influencing the purchase decision.

TCI=(Number of purchases made after receiving information)/(Total number of purchases) x 100

Operating indicators

Lower Price Sales Conversion Rate (LPSCR)

The connection between price and sales is a crucial element in any business, particularly in a commercial microenterprise. Although having a lower price can be an effective tactic for attracting customers, it is not always the only reason why consumers choose to buy.

In order to measure the lowest price conversion rate, you must identify the products that have the lowest price compared to those of the competition and record the number of times these products are sold compared to other higher-priced products. This will allow you to assess whether it is the lowest price that determines the purchase decision.

TCBP=(“(Number of sales made at@the lowest price))/(Total sales) x 100

Physical Interaction Sales Conversion Rate (PISCR)

The sensory experience of consumers, that is, the ability to see and touch products, is a crucial element in the purchase decision, particularly in the case of a commercial microenterprise. Facilitating physical interaction between customers and products can increase their confidence and satisfaction, which simplifies the sales process.

To measure the TCVIF indicator, it is necessary to observe and quantify the number of times customers touch or examine a product and then purchase it, compared to the total number of physical interactions customers have with the products for sale. This indicator measures the effectiveness of allowing customers to physically interact with products to make a sale more likely.

TCVIF=(“(Number of sales made after @customer physically interacts with the product))/(Total physical interactions) x 100

Peak Hour Sales Conversion Rate (TCVHP)

It is essential to maintain organization when serving numerous customers to ensure a rewarding experience, prevent misunderstandings, and boost sales in a commercial microenterprise. An orderly environment and efficient service can have a significant impact on customer satisfaction and the team’s ability to make sales.

To measure this indicator, it is first necessary to identify the times when the microbusiness has the highest customer traffic, record the sales made during these periods, and compare this with the number of customers served. This information will reveal the efficiency of staff in closing sales at times of high demand.

TCVPH=(“(Number of sales made@ during peak hours))/(“(Total number of clients served@ during peak hours)) x 100

Customer Satisfaction Rate with Service and Quality (CSR)

High-quality products and efficient service are two key elements in ensuring sales in a commercial microenterprise. Consumers are not only looking for products that meet their expectations, but also a rewarding purchasing experience that encourages them to return and recommend the microenterprise.

To measure this indicator, a two-question survey should be administered to customers. The first question should ask about their satisfaction with the service and attention they received at the time of purchase, and the second question should relate to their perceived quality of the product purchased. The two questions will be measured on a 5-point scale, where 1 is “very dissatisfied” and 5 is “very satisfied.” The result will be calculated by taking the average for each of the questions; this will provide a direct measurement of customer perceptions of product and service quality.

In practical terms, the results imply that management indicators designed from a complexity perspective can become strategic tools for microentrepreneurs, facilitating decision-making, competitive improvement, and sustainability. However, among the limitations of the study are its focus on a single district and the application of a cross-sectional design, which restricts the generalization of the findings.

Future research should expand the territorial coverage, apply longitudinal approaches, and consider digital metrics associated with the technological transformation of microenterprises. This will validate and strengthen the proposed model, generating useful inputs for both business management and the formulation of public policies that promote the resilience of MSMEs.

CONCLUSIONS

Research on the management of commercial MYPEs in the district of Tarapoto has generated significant findings that support the fundamental importance of customer relationship management for business success. The study, supported by a rigorous methodological analysis that included construct validation and a structural equation model with acceptable fit indices, demonstrated that interactions with customers are the only factor that directly influences management objectives (p=0,001), while interactions with other actors (suppliers, competitors, and regulators) showed no significant influence.

In response to these findings, a comprehensive measurement system was developed, consisting of product, information exchange, and operation indicators that provide specific metrics for evaluating and improving critical aspects such as inventory management, customer communication, and service quality. This framework of indicators, together with empirical evidence on the centrality of customer relationships, establishes a solid basis for strategic decision-making in MSMEs, offering practical tools to optimize business performance and strengthen competitiveness in the local market.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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