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Mechanisms of communication-control (social cybernetics) based on information technologies and local development

Miguel Inga-Avila[a*], Roberto Líder Churampi-Cangalaya[b], Jesús Ulloa-Ninahuamán[a], José Luis Inga-Avila[c], Luis Antonio Visurraga Camargo[b], Enrique Mendoza Caballero[d] and Kiko Richard Lopez Coz[e]

[a]*Universidad Nacional del Centro del Perú, Peru*
[b]*Altoandina National Autonomous University of Tarma (UNAAT), Peru*
[c]*Pontifical Catholic University of Peru (PUCP), Peru*
[d]*San Luis Gonzaga National University (UNICA), Peru*
[e]*Peruvian University Los Andes (UPLA), Peru*

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A B S T R A C T

Social cybernetics, as an interdisciplinary field, has gained increasing interest in the last decade due to the influence of information technologies in society through connectivity, Internet of things, process automation, artificial intelligence among others. This research focuses on exploring the relationship between social cybernetics (communication and control mechanisms) based on information technologies and local development, using structural equation modeling as an analytical tool. The design was non-probabilistic, with a sample of 482 people. The independent variables under study were Use of ICT for communication between local authorities and the population (CAP), Use of ICT for collaboration between public and private institutions (CPPC), Use of ICT for shared decision making (SDM), Use of ICT for local development planning (LDP) and Use of ICT for knowledge management (KM); and the dependent variable was Local Development (LD). It was determined that there is a relationship between all of them except with CAP. The direction and magnitude of the other ratios were: + 0.1390; - 0.3661; + 0.4472 and + 0.8432 respectively. The coefficient of determination (R2) was 93.69% facilitating the prediction of future results. The model has an adequate fit.

1. Introduction

From itself, reality, composed of multiple relationships of friendship, family and work, configures a complex system (Barabási & Bonabeau, 2003); in this context, cybernetics emerges as a fundamental tool to understand the complexities of human systems and society (Negoita, 1982). Its role is crucial to understand and incorporate these systems into the social dynamics, thus avoiding negative results when intervening them (Gupta, 1981). In Peru, the authorities of regional, departmental, provincial or district capitals are a key component for the construction of a modern society, since they concentrate their population, economic activities and basic public services; therefore, it is essential that they consider the new paradigm that cities should be designed, grow and develop in an orderly and adequate manner, ensuring a good standard of living and quality of life for their inhabitants. In view of this, cybernetics, a term coined by Wiener (1948), known as "the science of communication and control in machines and animals", has been taken up again as a strategic tool for the management of complexity; in this case, social complexity; allowing the integration of communication, coordination and control mechanisms to the operational and functional dynamics of cities (Wiener, 1950). In this regard, Espejo (2015) points out that a well-planned city can offer

* Corresponding author.
E-mail address miguelinga@uncp.edu.pe (M. Inga-Avila)

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easy access to public services, reduce travel times, improve safety and promote peaceful coexistence among its inhabitants. In this sense, Scott (2021) argues that social cybernetics can be used to improve local development by promoting communication, collaboration and shared decision-making among the different stakeholders. Zwitter (2024) proposes the concept of "cyber governance" as a set of adaptive principles applicable to an increasingly complex digital and intelligent society. On the contrary, a disorderly growth of cities can generate serious drawbacks such as vehicular congestion, air pollution and lack of spaces; therefore, the incorporation of disciplines that help to understand social behavior are important to avoid these drawbacks (Geyer & Van der Zouwen, 1991).

At the beginning of the century, Scott (2001) deepened the relationship between cybernetics and social sciences, distinguishing between the perspective of the observer and that of the observer of the observer (first and second order cybernetics, respectively) allowing to broaden the understanding of the functioning of society. In more recent experiences, Altobelli (2023) shows how cities in Italy have been able to be regulated and self-regulated through Green Pass which was inspired by cybernetic foundations; this is nothing but a balance between attenuators and variety amplifiers (very typical of variety engineering) in order to manage the complexity of reality (Schwaninger & Ott, 2024). Likewise, Becker et al. (2023) consider that a city focused on the structural implementation of technology, seeks to solve problems that afflict citizens; this approach being much more ambitious and necessary, but at the same time with high levels of responsibility and respect for spaces and proper use of the information generated in the processes. According to Baron et al. (2012), the best platform for sharing energy, ideas and enthusiasm to build a movement towards a more sustainable future are cities. Furthermore, the concepts of cybernetics are not limited to the social sphere; their reach extends to organizations, government and the state, where they can also be successfully applied (Rodríguez-Ulloa, 2022). In Peru, digital government concepts and applications are advancing and are under the responsibility of the Presidency of the Council of Ministers, through the Secretariat of Government and Digital Transformation.

Considering that information and communication technologies (ICTs) are a set of tools that enable the processing, storage and transmission of information (Laudon & Laudon, 2020), it is vital to strengthen communication, collaboration and shared decision-making among the different actors involved in local development, be they citizens, political, civil, police, judicial authorities, entrepreneurs, university students, civil collectives, among others. Now that information technologies (IT) have been democratized, their use is strategic for decision making and the promotion of action plans aimed at solving social problems and oriented to local development.

Local development is understood as the process of improving the economic, social and environmental conditions of a territory; it can be promoted through a series of strategies, including investment in infrastructure, job creation and improved education and training. In this sense, local policies need to consider economic and social elements of global character and experience, promote innovation using emerging technologies, continuously adjust to changes in both public and private institutions, and take advantage of the variety of talents and resources available (Petroccia et al., 2020). This requires governmental and institutional decision makers to take leading roles based on the theories of governance and public administration (Algotson & Svensson, 2021).

This article discusses the role of ICT-based communication-control mechanisms (social cybernetics) in local development, improving communication, collaboration and decision making, using structural modeling equations (SEM-PLS) as a tool for analyzing and understanding the relational dynamics of these variables, creating a solid basis for extending effective strategies for sustainable local development.

The research is based on the intersection of social cybernetics and local development, with the objective of understanding the influence of technologies on local social systems and addressing the challenges faced by communities in their use for development. To this end, a methodological approach based on structural models will be employed, allowing for an analysis of social and economic dynamics. Ultimately, the research seeks to establish reflections and discussion regarding strategies to improve quality of life, foster citizen participation and strengthen citizen participation of local communities through approaches based on social cybernetics.

2. Literature review

2.1 Structural equation models (SEM)

Ruíz (2010) describes them as multivariate statistical models that compute the cause-effect correlations between variables, including measurement errors in the dependent and independent variables, and give the regression models some slack. Because structural equation models allow one to propose and test the type and direction of relationships between the variables that make up the model, as well as estimate parameters and indicators to confirm the connections from the base theory, it is possible to design and statistically test the relationships that are proposed in the models (Byrne, 2010). Researchers may model and estimate complicated interactions among several dependent and independent variables at the same time by using SEM. The ideas that are being discussed are usually not visible and are gauged indirectly using a variety of indications (Hair et al., 2021).

2.2 Social cybernetics - Mechanisms of communication and control in cities

Luhmann (1995) discusses how social systems are organized and function through communication and interaction among their elements. He also addresses the notion of complexity in social systems and how this complexity can be managed through mechanisms of self-regulation and adaptation; in this sense, social cybernetics is an approach that seeks to apply cybernetic principles in the field of social and organizational interactions. It is based on the idea that social systems can be understood and managed in a manner similar to how cybernetic systems are managed, focusing on feedback, communication and self-regulation. In the context of sustainability, social cybernetics plays an important role by focusing on the complexity of social, economic and environmental problems, and how these dimensions interact with each other (Schwaninger & Ott, 2024).

2.3 Local development

Sachs (2015) indicates that local development refers to the process of promoting sustainable and equitable growth at the level of local communities, considering present and future needs, as well as the capacity of the environment to meet those needs without causing irreversible negative effects on it. Gori & Sodini (2020) consider local development as the capacity of a territory to improve its economic future and the quality of life of its inhabitants. For this local development to be resilient, harmonious and sustainable, it is important to find innovative and strategic solutions that balance its internal and external varieties (Espinosa & Walker, 2011).

3. Research model

The model that governs the research is shown in Fig. 1 and is based on the definitions and descriptions regarding communication and control mechanisms raised by Wiener (1948) and Wiener (1950) oriented to the use of information and communication technologies (ICT) and the contributions of Sachs (2015).

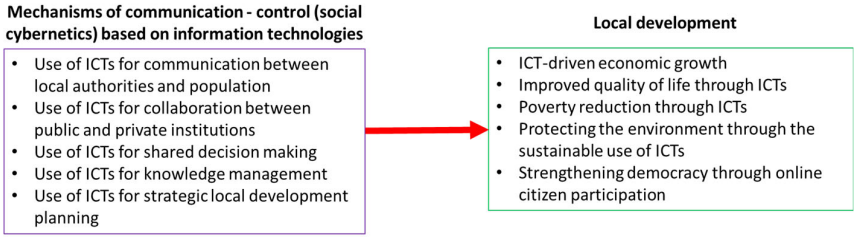

Fig. 1. Research model
Based on: Wiener (1948), Wiener (1950), Espejo (2015), Sachs (2015).

This proposal is transferred to a structural model using the SmartPLS Software v. 4.1.0.2 (Ringle et al., 2024) in which the dependent variable (local development) and independent variable (communication and control mechanisms - social cybernetics based on information technologies) are represented. See Fig. 2.

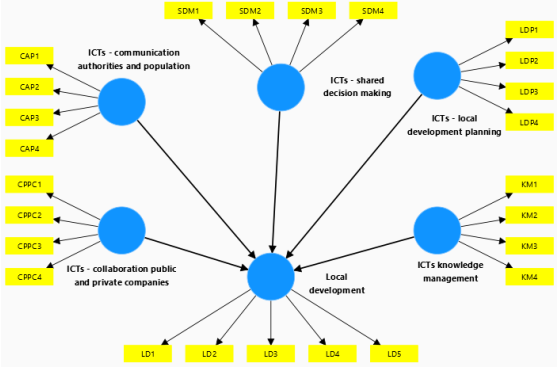

Fig. 2. Research Model Design with SmartPLS
Based on Fig. 2 and the relationships, the following study hypotheses are proposed:

- Hypothesis 1 (H1): The use of ICT for communication between local authorities and the population (CAP) are positively related to Local Development (LD).
- Hypothesis 2 (H2): The use of ICT for collaboration between public and private institutions (CPPC) are positively related to Local Development (LD).
- Hypothesis 3 (H3): The use of ICT for shared decision making (SDM) are positively related to Local Development (LD).
- Hypothesis 4 (H4): The use of ICT for local development planning (LDP) are positively related to Local Development (LD).

- Hypothesis 5 (H5): The use of ICT for knowledge management (KM) are positively related to Local Development (LD).

3.1 Participants

PLS is a technique that addresses the problem of correlations between complex variables when the data sample size is limited using SEM (Structural Equation Modeling). For the SEM approach, a minimum data sample size of 100 is required (Ghozali & Latan, 2017); therefore, the study was conducted with a total of 482 people, all of whom were of legal age, inhabitants of the districts of El Tambo, Huancayo Cercado and Chilca. Also according to Hair et al. (2017), the sample size should be at least 10 times the number of existing arrows in the model under study. The demographic details of the sample are detailed in Table 1 and lines below.

Table 1
Demographic details of the sample (N = 482).

Demographic data		Frequency *(f)*	Percentage (%)
Gender	Male	325	67.43%
	Female	157	32.57%

The mean age of the research participants was 41.8 years with a standard deviation of 3.22. With regard to the characteristics based on education, the focus was on collecting information from those with higher education (university or high school) and professional studies, without discarding those who did not have them.

Table 2
Distribution of participants by academic background

Education	Q	%
No profession	34	7.05%
High school / university student	152	31.54%
Professional graduate	99	20.54%
Professional	197	40.87%

3.2 Instrument

The data collection instrument was a questionnaire, which was constructed by the authors taking as a reference the theoretical bases reviewed and is composed of 25 items, distributed in the 5 independent variables: Use of ICT for communication between local authorities and the population (CAP), Use of ICT for collaboration between public and private institutions (CPPC), Use of ICT for shared decision making (SDM), Use of ICT for local development planning (LDP) and Use of ICT for knowledge management (KM); and in the dependent variable Local Development (LD). The items were evaluated with a Likert scale that rated them from 1 (Strongly disagree) to 5 (Strongly agree). The instrument was made available virtually to the study participants through Google Forms. The confidentiality of the data is assured, and there is a record of the informed consent and Responsible Conduct of Research (CRI) established by CONCYTEC.

4. Results

4.1 Confirmation of the measurement model

The calculation of the PLS algorithm, which has already been implemented, is used to assess the validity and reliability of the measurement model. This algorithm seeks to calculate discriminant validity, convergent validity (indicator validity and Average Variance extracted -AVE-), internal consistency -Cronbach's alpha and composite reliability- (Hair, Hult, Ringle, & Sarstedt, 2017). According to Martínez & Fierro (2018), based on theory and experience, the indicated tests should be performed to correlate constructs and indicators by means of factor loadings. The results of the evaluation of the measurement model are shown in Table 3.

Table 3
Results of the measurement model

Constructs	Load range	Reliability		Validity Convergent	Discriminant validity
		Cronbach's alpha	Composite reliability	Variance extracted mean	
Use of ICTs for collaboration between public and private institutions (CPPC)	0.86 - 0.89	0.8965	0.8988	0.763	0.8735
Use of ICTs for communication between local authorities and the population (CAP)	0.76 - 0.85	8338	0.8476	0.6671	0.8168
Use of ICT for knowledge management (KM)	0.71 - 0.89	0.8595	0.8696	0.7079	0.8414
Use of ICT for local development planning (LDP)	0.84 - 0.91	0.9115	0.9118	0.7909	0.8893
Use of ICT for Shared Decision Making (SDM)	0.87 - 0.92	0.9159	0.9272	0.7981	0.8934
Local development (LD)	0.79 - 0.95	0.9219	0.9272	0.766	0.8752

Given that all the items' factor loadings, as reported by Hair et al. (2014), fall between 0.71 and 0.95 on average—values greater than 0.7—it is evident that all the items are convergently valid. In addition, it can be said that the variables under investigation are legitimate because all the AVEs have values higher than 0.50. Similar results are obtained for the Composite Reliability and Reliability (Cronbach's alpha), both of which indicate a strong internal consistency with values over 0.8 (Nunnally, 1978; Nunnally & Bernstein, 1994). The degree to which one variable differs from the others is indicated by discriminant validity (Hair et al., 2017). The Fornell-Larcker (1981) criteria was applied for the corresponding calculation, considering the requirement that the AVE be larger than the square of the correlation with any other variable. Every time, the presumption was true.

4.2 Evaluation of the structural model

We assessed the associations between the latent variables after verifying the measurement model and reliability. By examining the path or path coefficients (see Fig. 3) and their corresponding significance levels, the hypotheses were assessed. For each of the route coefficients, bootstrapping was carried out using 5000 subsamples at a significance threshold of 0.05.

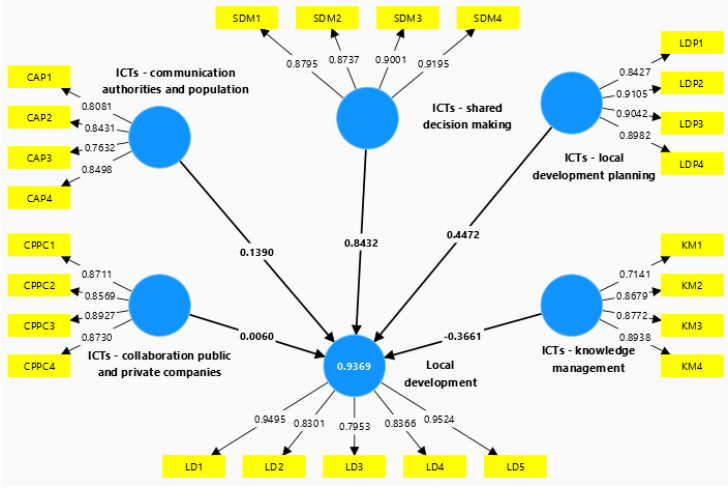

Fig. 3. Confirmatory structural model

The results in Fig. 3 are accompanied by Table 4 by means of which the stated hypotheses are evaluated in order to accept or reject them. The p-value and decision are included.

Table 4
Results of the structural model analysis

Hypothesis	Simple average	Standard deviation	Path value (beta)	Statistic t Student	p-value	Decision
H1: CPPC → LD	0.0331	0.1146	0.0060	2.0526	0.122	H1 is rejected
H2: CAP → LD	0.1291	0.0887	0.1390	2.5682	0.001	H2 is accepted
H3: KM → LD	-0.4484	0.3028	-0.3661	3.2090	0.000	H3 accepted
H4: LDP → LD	0.4317	0.0545	0.4472	8.2011	0.004	H4 accepted
H5: SDM → LD	0.9247	0.3243	0.8432	2.6003	0.003	H5 accepted

$t > 1.96$; $p < 0.05$

Based on the results shown, H1 is rejected and the other hypotheses (H2, H3, H4 and H5) are accepted. The Use of ICT for communication between local authorities and the population (CAP) maintains a weak and positive relationship ($\beta = 0.1390$, $p<0.005$) with Local Development (LD); the Use of ICT for knowledge management (KM) maintains a medium and negative relationship ($\beta = -0.3661$, $p<0.005$) with Local Development (LD); Use of ICT for local development planning (LDP) maintains a medium and positive relationship ($\beta = 0.4472$, $p<0.005$) with Local Development (LD); finally, Use of ICT for shared decision making (SDM) maintains a strong and positive relationship ($\beta = 0.8432$, $p<0.005$) with Local Development (LD). The relationship Use of ICT for collaboration between public and private institutions (CPPC) and Local Development (LD) is not accepted as it is not significant ($p>0.05$). The most common evaluation metric for structural models is the R2, also known as the coefficient of determination, which is a measure of the predictive accuracy of the model. This value represents the combined effect of the exogenous latent variable on the endogenous latent variable (Hair et al., 2017). In the present study, the R2 value indicates that the model expresses collectively and in interaction a predictive capacity of 93.69%.

5.3 Model adjustment

After validation of the measurement and structural models, several goodness-of-fit (GoF) tests were performed.

Table 5
Goodness of fit

Indicator	Results	Indicator
SRMR	0.083	acceptable if <= 0.1
d_ULS	2.315	acceptable if >= 0.95
d_G	1.642	acceptable if P >= 0.05
Chi-square	112.3	close to zero
NFI	0.86	acceptable if >= 0. 90

Hu & Bentler (1999); Byrne (2010).

Based on the results, it is established that the model has an adequate fit.

6. Discussion of Results

Regarding the Use of ICT for collaboration between public and private institutions (CPPC) and Local Development (LD)

In the present study, the relationship between the Use of ICT for collaboration between public and private institutions (CPPC) and Local Development (LD) has not been demonstrated given that the p-value obtained is greater than 0.05, so H1 is rejected. Despite the fact that this hypothesis -for the purposes of the study is not taken into account- the relationship it shows with local development is very weak (path value = 0.006); this value calls for reflection since it would be demonstrating the little articulation not only of those who lead public and private institutions with local development, but an almost null articulation between them. Even when there are state portals, specialized software proposed by the Secretariat of Government and Digital Transformation and ministries such as Invierte.pe; SIAF, SIGA, CEPLAN, among others, there is no sharing of information or experiences among the various agencies. This reality is contrary to the proposals of Almeida et al. (2023) and Algotson & Svensson (2021) who promote a close dialogue between the various public and private institutions for the coordination of joint actions aimed at generating jobs and improving the economy, with the participation of universities and the civil population.

Regarding the Use of ICTs for communication between local authorities and the population (CAP) and Local Development (LD)

The research has shown that the Use of ICT for communication between local authorities and the population (CAP) has a weak positive influence (path value = 0.1390) and significant (p-value = 0.001) on Local Development (LD), so Hypothesis 2 (H2) is accepted. This result coincides with the conclusions presented by Chessman (2022) who states that the worst weakness of state institutions and their own authorities is their precarious articulation and coordination among their own levels and with the population. Again, Algotson & Svensson (2021) express their interest in the assumption of greater protagonism of political and social actors to meet the needs of the population. Furthermore, by offering avenues for communication with the government and facilitating more effective and efficient information dissemination to citizens and organizations, the use of information and communication technologies (ICTs) in public organizations enhances accountability, transparency, and public participation (Yavuz & Welch, 2014). Although it is true that there are public hearings, these are face-to-face, do not make use of Information Technology (IT) and become more of a proselytizing or political publicity activity, rather than listening to the demands of the population. The same happens with the Participatory Budget where authorities and population "apparently" decide which works and actions should be executed for local development, unfortunately when reaching executive decision levels, many of these are dismissed, causing discontent and protests (Marticorena, 2020).

Regarding the Use of ICT for Knowledge Management (KM) and Local Development (LD)

Regarding the Use of ICT for knowledge management and Local Development (LD), these maintain a weak negative influence relationship (path value = - 0.3661) and significant (p - value = 0.000) accepting Hypothesis 3 (H3).

The weak relationship shown in the study highlights the lack of continuity of work experience in public institutions (regional government, provincial municipalities, district municipalities, governors' offices, etc.) due to staff turnover every time there is a change of authorities. Even when the existing computer equipment, hardware and software are bequeathed and the personnel whose status is appointed or permanent keeps the job and the knowledge; it is rarely shared with their work colleagues, generating delays and delays in learning, to the detriment of the quality of the service to the user. The National Civil Service Authority (SERVIR), through the National School of Public Administration, has arranged a series of MOOC courses in order to share information and experiences among public sector employees. In this regard, Inga-Avila et al. (2023) expressed the importance of the use of information technologies (IT) in the sharing of individual and collective experiences in order to preserve best practices in public institutions, companies and businesses.

Regarding the Use of ICT for Local Development Planning (LDP) in Local Development (LD)

The relationship between the Use of ICT for local development planning (LDP) and Local Development (LD) is positive on average (path value = 0.4472) and significant (p-value = 0.004), thus accepting Hypothesis 4 (H4).

The Urban and Territorial Development Office of the Provincial Municipality of Huancayo is in charge of planning, directing, executing and supervising the actions related to the Urban and Territorial Development Plan of the province, as well as managing the cadastre (which includes generating the cadastre map with geographic information systems) and promoting sustainable urban growth. Being a work of technical and specific nature, the relationship shown by the results is consistent and reflects the defined use of Information Technologies (IT). However, local governmental efforts should not be limited to merely administrative or isolated tasks, but rather to a joint effort aimed at city planning based on criteria such as access to basic services, safety, context, functionality, climate, topography, etc., in order to ensure the quality of life of the inhabitants and enable them to contribute with their taxes to make the locality sustainable. In this regard, Allen (1998) argues that sustainability and local development requires smart urban planning, urban participation and citizen empowerment, resilient and adaptable cities, sustainable and efficient mobility, smart and energy efficient buildings, transparent and corruption-free governments, and entrepreneurial communities; in each of these considerations, it is possible to include information technologies (IT) such as: wireless cellular communication, Internet of things, smart sensors, startups, artificial intelligence, chatbots and virtual assistants, big data, blockchain, renewable energies, etc.

The experience of cities such as Barcelona in Spain described by Mariona (2023), allow to propose initiatives, for example: digital state formalities, intelligent traffic lights that respond according to vehicular and pedestrian flow, 360 video surveillance cameras for citizen security, photo ticket cameras to regulate vehicular speed on streets and highways, lights with solar cells and photosensors, wind energy generation, use of organic waste, improvement of roads and highways to promote public transport with mobile applications that allow time to be used, electronic payment systems, biometric controls, among others. To create a "smart city", it is necessary to follow the rules for its creation: human orientation, adaptability of urban infrastructure, improving the quality of urban resource management, comfortable and safe environment, emphasis on economic efficiency, including the service component of the urban environment (Reutov, 2023).

Use of ICT for Shared Decision Making (SDM) in Local Development (LD)

Finally, this study indicates a strong positive and significant relationship (path = 0.8432 and p-value = 0.003) between the Use of ICT for Shared Decision Making (SDM) and Local Development (LD). Although the results are valid, the authors consider that this relationship is not factual. In theory, the results are in line with what Algotson & Svensson (2021) indicate; however, in practice, the decisions made by the drivers of the institutions are not consensual and respond to personal rather than collective interests. Therefore, it is necessary to promote articulated, relational and pragmatic agents as proposed by Rowe et al. (2024).

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