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Impact factors in innovation management. Vision from the state companies

Factores de impacto en la gestión de innovación. Visión desde empresas estatales

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Abstract

Innovation is becoming an increasingly important factor in the world's economies, and therefore a timely solution to problems in companies and their contribution to the sustainable development of society. One of the first steps for its successful operation is to analyse the conditions that exist in companies and the factors that affect them. The objective of this study is to identify the impact factors on innovation management in Cuban state-owned enterprises. A Bayesian network model was constructed to analyse the behaviour of the process in several state-owned enterprises in the province of Camagüey, which are strategically important to the country. The results indicate that among the factors with the greatest impact are: leadership of innovation activities, documentation or registration of processes and their results, and the organisation's links with other entities. It can be concluded that the tools of

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document, information and knowledge management, in their continuous interrelation, are factors that favour innovation management.

Keywords: Innovation; Innovation management; Bayesian networks; State-owned enterprises.

Resumen

La innovación resulta cada vez más eje principal de las economías en el mundo y por tanto solución oportuna de los problemas en las empresas y su contribución al desarrollo sostenible de la sociedad. Uno de los primeros pasos para su exitoso funcionamiento, es analizar las condiciones que existen en las empresas y los factores que inciden. La investigación tiene como objetivo identificar los factores que tienen impacto para gestionar adecuadamente la innovación en las empresas estatales cubanas. Se construyó un modelo de Redes Bayesianas para medir la eficiencia del proceso en diversas empresas estatales de la provincia de Camagüey, pertenecientes a sectores estratégicos del país. Los resultados muestran que entre los factores de mayor impacto se encuentran: Liderazgo de las actividades de innovación, Documentación o registro de los procesos y sus resultados, Vínculos de la organización con otras entidades. Se concluye que las herramientas de la gestión de documentos, de información y el conocimiento, como factores, en su continua interrelación, favorecen a la gestión de la innovación.

Palabras Clave: Innovación; Gestión de innovación; Redes bayesianas; Empresas estatales.

1. Introduction

In the current business environment, characterised by constant change, innovation becomes an alternative that responds to the challenges that arise. However, the factors that influence its successful application are dissimilar, and therefore, companies must consider those that can be controlled by the organisation (Miller *et al.,* 2020).

In this context, the Organisation for Economic Co-operation and Development (OECD, 2018) posits that innovations originate from knowledge-based activities, which entail the practical application of existing or newly developed information and knowledge. Information, in turn, is defined as organised data that can be reproduced and transferred through documents. This indicates a relationship between documents, information and knowledge that is reinforced by their management.

Sosa *et al.* (2024) posit that innovation and knowledge management are inextricably linked, with knowledge management employing a range of tools, including information management, environmental monitoring and strategic intelligence, as well as document management, to support information on business activities. However, a review of the literature reveals a methodological shortcoming, namely that it does not sufficiently examine the synergistic relationship between the components of KMKM as the basis for the design or implementation of methodologies, models, strategies or procedures for innovation.

In this context, authors such as Abdi *et al.* (2018) and Lee *et al.* (2021) have identified factors that influence innovation without addressing the relationship between the components of the GDIC for the GI. Cuban authors, such as González and Lavandero (2018), Díaz (2018, 2019), Arencibia *et al.* (2019), and Ávila *et al.* (2020), have also conducted research on KM in Cuban state-owned enterprises, identifying and evaluating factors that contribute to the success or failure of business innovation. However, they have not addressed the fact that the lack of synergy between knowledge, information and document management is the generator of many of these factors or affects the severity of their impact on innovation management.

In their research on KM in Cuban state-owned enterprises, Ávila *et al.* (2020) and Delgado (2022) identify and evaluate factors that contribute to the success or failure of business innovation. However, they do not examine the fact that the lack of synergy between knowledge, information and document management is the generator of many of these factors or affects the severity of their impact on innovation management.

The objective of the present work is to identify, from a probabilistic perspective, the relationships between the factors that have had an impact on innovation management in Cuban state-owned enterprises up to the present. The impact factors will be identified as those variables that integrate the GDIC and the IG itself, through the construction of a Bayesian Network Model (BR) using the Python programming language.

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The results of the scenario analysis permit the prediction of those variables that exert the greatest impact on the GI. This information is of value to companies, enabling them to identify, comprehend and utilise the factors that drive and influence the GI.

2. Theoretical Framework

The term "innovation" can be defined as either an activity or a process, or the result of these. It can be new or improved (or a combination of both), but which differs significantly from the previous ones. The most important aspect is its implementation (OECD, 2018). Innovation requires knowledge creation, development, application and use activities. The term "knowledge" is defined as the comprehension of information and the capacity to utilise it for diverse purposes, including the generation of novel ideas, models, methodologies, or prototypes that can serve as the foundation for innovations (OECD, 2018). The aforementioned evidence illustrates the intricacy of the innovative process, which is predicated on the generation and application of knowledge, and is founded upon information that is documented in written form.

In the view of Sosa *et al.* (2022), the relationship between these three elements (documents, information and knowledge) requires management that promotes the correct treatment and flow of documentary sources, information and knowledge generated to develop or increase innovations. Furthermore, they regard them as impact management processes that contribute significantly to the intervention and support of strategic decision-making in organisations in an effective and safe manner. They concur with Martínez *et al.* (2022) that impacts are the effects of multiple manifestations that have a diversity of expressions and meanings. Consequently, it is essential to be aware of the characteristics and components of these processes and the operations of each one of them in order to comprehend the nature of their impacts.

As defined by Font (2013), document management encompasses the life cycle of documents generated by the organisation as a result of its functions, acts, and transactions within business processes and decision-making. This ensures the organisation's access to and rapid retrieval of the documentary types created, facilitating the analysis of information derived from them.

In order to achieve this, it is necessary to utilise archival instruments that facilitate the organisation, control and accessibility of the documents generated by the organisation's processes or activities (Font, 2013). These instruments contribute to the documentation or recording of the processes and their results on the document management policies within the organisation (decrees, resolutions, current standards) that regulate their treatment (International Organization for Standardization [ISO], 2015).

Information management is concerned with the life cycle of information generated within an organisation and its external environment. It ensures that the necessary information is provided and retrieved at the appropriate time, allowing the most appropriate decision to be made (Rodríguez, 2016).

Information management comprises three key components that warrant particular attention within the context of innovation management. These are technology watch, competitive intelligence and benchmarking. The technology watch is an organised approach to capturing and selecting external information on technology, which is then converted into organisational knowledge. This enables businesses to identify potential opportunities and anticipate changes in the environment, thereby reducing the risk associated with decision-making.

The process of competitive intelligence involves the gathering and analysis of information about competitors, both direct and indirect. This enables businesses to gain insight into their strategies and best practices, as well as to identify areas where they can improve their own processes and characteristics. Benchmarking is a fundamental tool in the search for external information, as it involves the study of competitors to understand their strategies and best practices. This enables businesses to identify areas where they can improve their own processes and characteristics. The

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second component, which is complementary to the first, emphasises the presentation of the information captured in a format suitable for business decision-making and the analysis and evaluation of the results of its use. The third component, benchmarking, is a fundamental tool in the search for external information since it consists of the study of competitors, direct and indirect, to understand their strategies and best practices used by them and reproduce, or adapt, those that fit the processes and characteristics of the organisation.

The field of knowledge management is responsible for identifying, acquiring, developing, sharing, distributing, using, and retaining individual knowledge in order to convert it into corporate knowledge (Rodríguez, 2016). This process is linked to the generation of ideas in terms of identifying and selecting the best decision alternative for problem solving. In this context, the creation of spaces for exchange represents an essential component in facilitating debate and analysis of ideas and conceptions, thereby facilitating the generation and dissemination of knowledge. This process is currently facilitated by the development of tools for collaboration and group work, such as social networks, intranet, web pages, email, and databases. As Artiles (2009) notes, each of these tools, based on the structuring of knowledge networks, promotes interaction and knowledge capture.

Although any member of the organisation may contribute to the creation of knowledge, it is necessary to identify those who are internal experts (employees of the organisation) and external experts (outside the organisation). An expert is defined as a person with experience and knowledge of a studied topic or of the operation of the company's fundamental processes. Their opinion can provide valuable information that is difficult to capture (Terán *et al.,* 2019).

Another component of knowledge management are collaborative projects, also known as innovation projects. These projects aim to enhance efficiency and utilise existing knowledge (Trzeciak *et al.,* 2022). As these projects are executed and positive and/or negative results are obtained, they constitute lessons learned. These are acquired experiences that constitute new knowledge. Finally, organisational knowledge is also generated by customer feedback. This occurs in the exchange that the organisation maintains with the customer to ascertain to what extent the organisation's products and services meet their needs and expectations (Lee *et al.,* 2021).

Each management process, with its distinctive characteristics, contributes to decision-making. However, the integration between them has a significant impact on the innovation process. While they can be developed independently, a systemic approach between them is necessary for successful decision-making (Sosa *et al.,* 2022), as Ponjuán (2005) points out, since synergy between them is a necessary condition and requirement of IM.

Miller *et al.* (2020) posit that the IG is structured by activities. These include the analysis of ideas for innovation projects, which necessitate the protection of resulting knowledge through industrial property methods, such as trademarks, patents, or others. Additionally, the control of the process to implement preventive and reinforcement actions is essential. The successful development of these activities and training programmes, as well as the training of the workforce to meet the demands of innovation, can be guaranteed through the use of monitoring and performance evaluation methods, as well as the guidance of the company's management, as proposed by Trzeciak *et al.* (2022). Furthermore, Trzeciak *et al.* (2022) emphasised the importance of the organisation's links with other entities in order to carry out innovation activities. This evidence demonstrates the diversity of components, factors and activities related to ICM that influence the proper functioning of IM. Accordingly, the authors of this article posit that the organisation, planning, management and control of business innovation is not feasible without considering its link and synergy with ICM and the particularities of each one of them. Consequently, it is of paramount importance to identify the processes and activities that contribute to IM, to gain an understanding of their interconnections, and to manage them as a unified entity.

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Innovation has been defined by various sources as the primary economic actor in business management in the Republic of Cuba. Its performance is crucial for the generation of wealth, a sustainable dynamic of growth, and the welfare of the population. Blanco (2023), Díaz (2018), Rodríguez and Núñez (2021) and others have highlighted this. In 2019, Blanco (2023) highlighted that for the Cuban state enterprise, innovation should be regarded as a key factor in improving its results, which therefore constitutes an essential element of its management. Nevertheless, the efficacy of innovation management in the biotechnology sector has not been demonstrated or generalized across other economic sectors. Furthermore, although there is a wealth of research on the subject, there are still significant gaps in the understanding of the synergistic relationships between ICM and IM processes.

3. Methodology

In order to achieve the proposed objective, a Bayesian Networks (RB) model was constructed. The RB methodology was employed to analyse the behaviour of GI in eleven state-owned enterprises in the province of Camagüey, which are strategically important for the country's economic and social development, including the food industry, energy and mining, construction and tourism. This methodology was selected on the basis of its potential applicability to the area of knowledge under study and its usefulness for modelling probabilistic relationships between variables. This approach can be beneficial when analysing complex and interrelated factors that influence IG, for representing dependencies between factors, which facilitates the interpretation of results and informed decision-making, and for managing uncertainty and variability in the data characteristic of innovation.

The model was constructed based on the information provided by 38 managers and managers in charge of IM in the selected companies, chosen based on the principles of convenience sampling. A survey was designed to capture this information. The dimensions and variables measured in the model were used as factors of IM and were formed from the analysis of models, procedures, methodologies and norms in force in the country, related to ICM and innovation. The final selection of these factors was made by specialists in the subject.

The data obtained from the instrument was tabulated using the Excel tool, which enabled the visualization of the status of each variable and the formation of the knowledge base that was subsequently utilized in the technological tool to construct the model. This model was developed using a mixed approach, in which the specialists established the structure, determined by the causal relationships between the variables, and the probabilities associated with these relationships were established using algorithms on the databases created with the information collected in the survey.

In order to identify the relationships between variables from a probabilistic perspective, a tool based on RB was utilised, employing the Python programming language and implementing an explanatory variant, which describes the research variables and their relationships, and a predictive variant for scenario analysis. The resulting analysis enabled the causality between the variables that have an impact on the management of the companies analysed to be identified, thus enabling the factors to be considered in their design.

4. Results and discussion

4.1. Bayesian Network Model applied to innovation management

In the construction of the RB model, the properties proposed by Terán *et al.* (2019) and the modelling elements proposed by Lopez (2017) were assumed. These criteria contributed to the modelling of the various variables of the study process and to an understanding of their relationships, levels of occurrence and behaviour in the organisation.

In the research, the following steps were followed for the modelling of Bayesian networks using the Python programming language:

- ***Step 1.*** Load the library to work with. The initial step is to load the library, which

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is the set of algorithms or tools that the software requires in order to function correctly. In this instance, the algorithm employed was RB.

- ***Step 2.*** Upload the files with the knowledge bases where the information about the variables appears.

In this step, the research variables and their values are identified, and the latter are coded for subsequent tabulation. This is done as a prior step to the design of surveys, interviews, or observations to be used to capture information on the behaviour of each variable. The information collected is tabulated, and the files that make up the database are created with the information on the variables that will be processed using computer media.

In the research, twenty-five variables belonging to the dimensions of CIMD and IM were identified (Table 1). The variables identified refer to the application, manifestation or use of processes and instruments characteristic of ICBM and IM. Consequently, their nature is descriptive. To measure the status of each and every one of them, values are assigned on a nominal three-item scale: yes, no, I do not know.

Table 1. Variables identified in the research

Dimensions	Variables
Document management	1.Document management tools
	2. Documentation or recording of processes and their results
	3. Defined policies regarding document management in the organization
Information management	1. Information systems in the organization
	2. Allocation of technological and communicative resources for information management.
	3. Design and Implementation of Surveillance and Intelligence
	4. Design and implementation of benchmarking
Knowledge management	1. Creation of spaces for exchange (idea generation)
	2. Identification of internal experts and the knowledge they bring to the organization
	3. Identification of external experts and the knowledge they bring to the organization.
	4. Creation of a database of external and internal experts and promotion of channels for them to interact
	5.Recording of periodic anal yses of the results of knowledge networks
	6. Creation of collaborative work projects among its members and with external experts.
	7. Use of tools for collaboration and group work
	8. Lessons Learned Systems
	9. Customer feedback
Innovation management	1. Ideas analysed for innovation projects
	2. Development of innovation projects
	3. Innovation Management Plan or Strategy
	4. Leadership of innovation activities
	5. Links of the organization with other entities to carry out innovation activities
	6. Workforce training, training or education program that responds to innovation needs
	7. Registration of trademarks, patents or other forms of industrial property
	8. Method of monitoring and evaluation of performance in the development of the I.G. Preventive and reinforcement actions
	9. Design and implementation of Innovation Management

Source: Authors' own elaboration.

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In order to tabulate the captured information, codes one, two and three are established for the respective values of the defined scale. The Excel worksheet provides the necessary tools for this purpose.

- ***Step 3. Construction of the Bayesian Networks model.*** In this step, the relationships between the variables identified by the specialists are presented. The most important variable, or inference variable, identified was Design and implementation of Innovation Management, so the remaining variables are probabilistically related to it. The sixth of these groups integrates ten variables or nodes, including the dependent or inference variable, which directly affects the inference variable, according to the specialists' assessments.

The variables included in the aforementioned group are as follows:

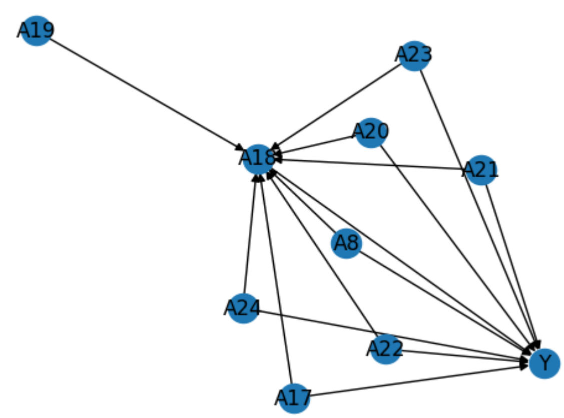
1. Development of innovation projects
2. Creation of spaces for exchanges (generation of ideas)
3. Ideas analysed for innovation projects
4. Innovation management plan or strategy
5. Leadership of innovation activities
6. Links of the organisation with other entities
7. Training programme
8. Registration of trademarks, patents
9. Method of monitoring and evaluation of I.G.
10. I.G. design and implementation

- ***Step 4. Estimate the maximum likelihood of the parameters (variables).*** In this step, the parameters of the data set or the distribution of the data set are estimated. A class of distribution with unknown parameters is specified, and the data is used to specify the values of these parameters. In probabilistic terms, this is the probability that a certain sample will occur or be given if the estimation that has been made or the estimator that has been proposed is true. The research followed the steps addressed by Ramírez (2020).

- ***Step 5. Estimate the parameters of the Bayesian networks or maximum a posteriori.*** In this step, unknown data is estimated, which is equated to the mode of the posterior distribution. This is used to obtain a point estimate of an unobserved quantity based on empirical data. In the research, the steps addressed by Ramírez (2020) were followed.

- ***Step 6. Draw* the Bayesian Network.** In this step, the relationships between the groups of variables and between all the variables and the inference variable are represented in graphs. In order to facilitate the reading and understanding of the tool used by researchers and readers, a code was assigned to each variable. This is shown in Figure 1, which represents the Bayesian network characterising the sixth group of variables, and its corresponding legend.

Figure 1. Bayesian networks of the sixth group of variables



Source: Authors' own elaboration.

CAPTION:

-A8 - Creation of exchange spaces

-A17- Ideas analysed for innovation projects

-A18 - Development of innovation projects

-A19 - Management plan or strategy

-A20 - Leadership of innovation activities

-A21 - Links with other entities

-A22 - Training Program

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Figure 2. Probabilistic relationships between the sixth group of variables and Y

A17	A17(0)	A17(0)	A17(0)	...	A17(2)	A17(2)	A17(2)
A18	A18(0)	A18(0)	A18(0)	...	A18(2)	A18(2)	A18(2)
A20	A20(0)	A20(0)	A20(0)	...	A20(1)	A20(1)	A20(1)
A21	A21(0)	A21(0)	A21(0)	...	A21(2)	A21(2)	A21(2)
A22	A22(0)	A22(0)	A22(0)	...	A22(2)	A22(2)	A22(2)
A23	A23(0)	A23(0)	A23(0)	...	A23(2)	A23(2)	A23(2)
A24	A24(0)	A24(0)	A24(0)	...	A24(1)	A24(1)	A24(1)
A8	A8(0)	A8(1)	A8(2)	...	A8(0)	A8(1)	A8(2)
Y(0)	0.5	0.5	0.5	...	0.5	0.5	0.5
Y(1)	0.5	0.5	0.5	...	0.5	0.5	0.5

Source: Authors' own elaboration.

-A-23 - Trademark registration

-A24 - Method of monitoring and evaluating the performance of the GI

-Y - Design and implementation of IM

In the network, a dependence/independence relationship is defined between the variables. From this perspective, it can be stated that A8, A17, A19, A20, A21, A22, A23 and A24 are independent variables with respect to A18. Consequently, any alteration in these variables will affect A18, but this does not necessarily imply that the other variables will present a variation. In a similar manner, the variables A8, A17, A18, A19, A20, A21, A22, A23 and A24 are independent variables of Y. Any alteration in their behaviour will consequently have an effect on the latter.

- ***Step 7. Print all conditional probabilities from the model.*** The calculation of all conditioned probabilities has been completed. In this case, all possible combinations of conditioned variables with respect to Y have been considered. The above information is exemplified in Figure 2.

Figure 2 illustrates the conditional probabilities of the variables A17, A18, A20, A21, A22, A23 and A24, A8, which are employed to derive the probabilities of Y. Consequently, for each of the values identified in the aforementioned variables, the probable outcome to be output is 0.5 for Y.

- ***Step 8. Calculate the probabilities of identifying the inference variable from the model variables.*** In the present investigation, the variable of inference is Y. In this step, given some selected variables, how can the variable Y be inferred, taking into account their relationships? Figure 3 shows the inference of Y with respect to variables A23 and A8. The value of Y is inferred by variables A23 and A8, considering the Bayesian probabilities calculated from the knowledge base. Therefore, the most probable value is Y(1), because its probability is higher than that of Y(0).

Scenario analysis is conducted by answering multiple questions under the structure of "what if", by imagining numerous possible futures, and by examining the causal relationships between the variables that shape the scenarios (Delgado, 2021). Consequently, it allows the study of situations of risk or uncertainty, the assignment of values to the disparate situations that arise, and the association of a probability to each of them.

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Figure 3. Probabilities of inferring variable Y from A23 and A8

```
from pgmpy.inference import VariableElimination

    # Create inference object
infer = VariableElimination(modelo)

    # Calculate the probability of the design and implementation of the G.I (Y)
q = infer.query(['Y'], evidence={'A23': 0, 'A8': 1})
print(q)

+------+----------+
| AND      | phi (Y) |
+======+=========+
 | Y(0) |      0.4406 |
+------+----------+
 | Y(1) |      0.5594 |
+------+---------
```

Source: Authors' own elaboration.

By attending to the set of alternatives and making an overall assessment, the data will be weighted or averaged to identify the main factors and how each factor individually affects an event. This process allows for the identification of the most significant factors and their individual contributions to the outcome of an event. As Sánchez (2016) points out, this approach enables the conclusion to be reached on the choice to be made.

4.2. A Bayesian Network model was employed to conduct a scenario analysis for the purpose of innovation management

In order to perform the scenario analysis, the data from the knowledge base that has been processed in the preceding steps is employed. After being tabulated in Excel, the data indicates that there is an 89% probability that the innovation will be successful. The probability of the IG functioning effectively in the selected companies is 89%. However, there is a 68% probability that its operation will not be entirely efficient. This may be attributed to the fact that the variables that determine its operation were not considered with sufficient rigor during its design. Consequently, the selected specialists identified 13 variables for scenario analysis, focusing on those most likely to be related to GI (Table 2). These variables were grouped and., from step 3 (creating the RB model) to the end, the Python tool steps described in the previous sub-section were repeated, loading the software with the databases of the variables chosen.

In Step 8, modifications were made to the behaviour of the values (Yes: 1, No: 0, Don't know: 2) of each of the variables that comprise the BN. This was done in order to ascertain the impact of each variable and groups of variables on the outcome, by posing the question "What would happen if...?" (1: present, 0: absent, 2: unknown) and therefore, how this behaviour probabilistically influences, in each case, the dependent variable Y. The following section presents only those independent groups or variables that have a significant impact on the research. The preceding information is presented in Figures 4-9.

Upon examination of the potential scenarios resulting from the behaviour of variables A2, A4 and A7 (Figure 4), it becomes evident that only variable A2 exhibits an increase in its relationship with variable Y, with a probability of occurrence of 84.20%. Conversely, the probability of this occurring in the remaining variables does not exceed 50%.

The above result suggests that, although information systems are managed in the

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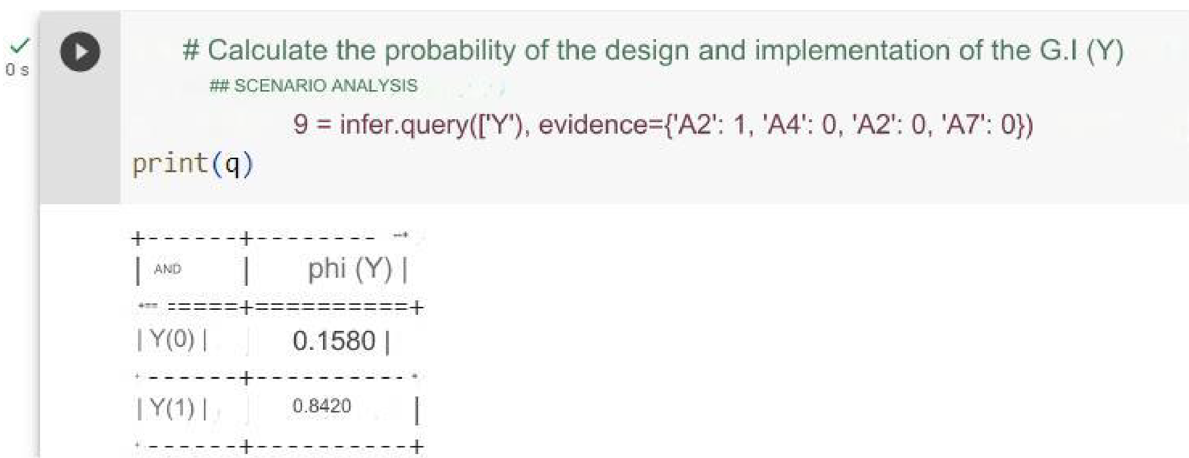
Table 2. Probabilistic relationship of the selected variables with GI

Variables	Probability
Documentation or recording of processes and their results (A2)	0.80
Information systems in the organization (A4)	0.85
Surveillance and intelligence design and implementation (A6)	0.87
Benchmarking Design and Implementation (A7)	0.85
Creation of spaces for exchanges (generation of ideas) (A8)	0.81
Creation of a database of external and internal experts and promotion of channels for them to interact (A11)	0.73
Lessons learned systems (A15)	0.61
Customer feedback (A16)	0.81
Ideas analyzed for innovation projects (A17)	0.89
Development of innovation projects (A18)	0.97
Innovation management plan or strategy (A19)	0.95
Leadership of innovation activities (A20)	0.87
Links of the organization with other entities for the realization of innovation activities (A21)	0.83
Training, coaching or workforce development programs that respond to innovation needs (A22)	0.83
Registration of trademarks, patents or other forms of industrial property (A23)	0.85
Method of monitoring and evaluation of performance in the development of IPM. Preventive and reinforcement actions (A24)	0.86
Source: Authors' own elaboration.	

Figure 4. Scenario analysis of variables A2, A4, A7 with respect to Y


```
# Calculate the probability of the design and implementation of the G.I (Y)
## SCENARIO ANALYSIS
9 = infer.query(['Y'), evidence={'A2': 1, 'A4': 0, 'A2': 0, 'A7': 0})
print(q)

+------+--------
| AND  |   phi (Y) |
=====+==========+
| Y(0) |   0.1580 |
------+----------
| Y(1) |   0.8420  |
------+----------+
```

Source: Authors' own elaboration.

organisation for innovation (variable A4) and benchmarking is designed and implemented (A7), it is the documentation or recording of the innovation management process and its results (A2) that exerts the greatest influence on the behaviour of IG. This result ratifies the need to document or record the processes and their results, which is so much advocated

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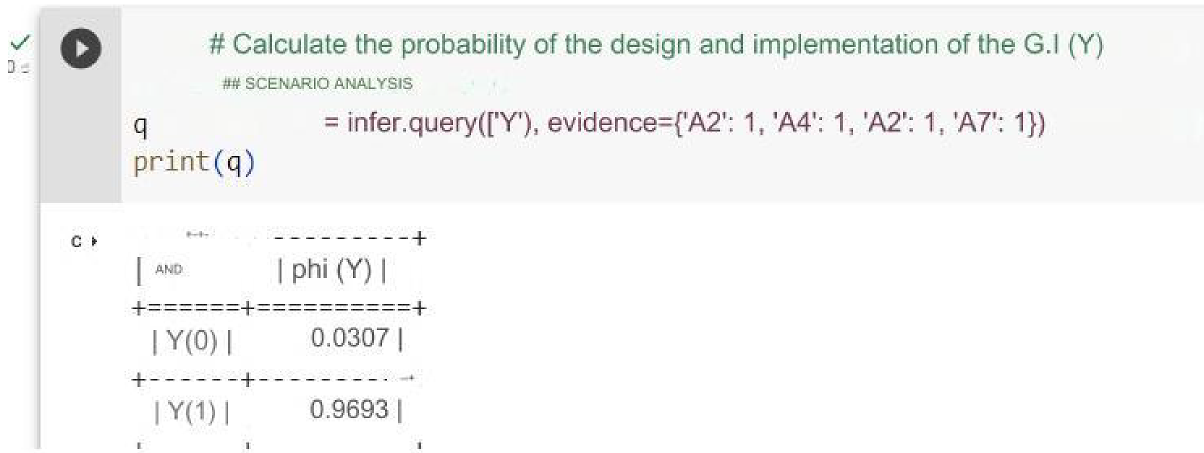
Figure 5. Scenarios of the group of variables A2, A4, A7 with respect to Y

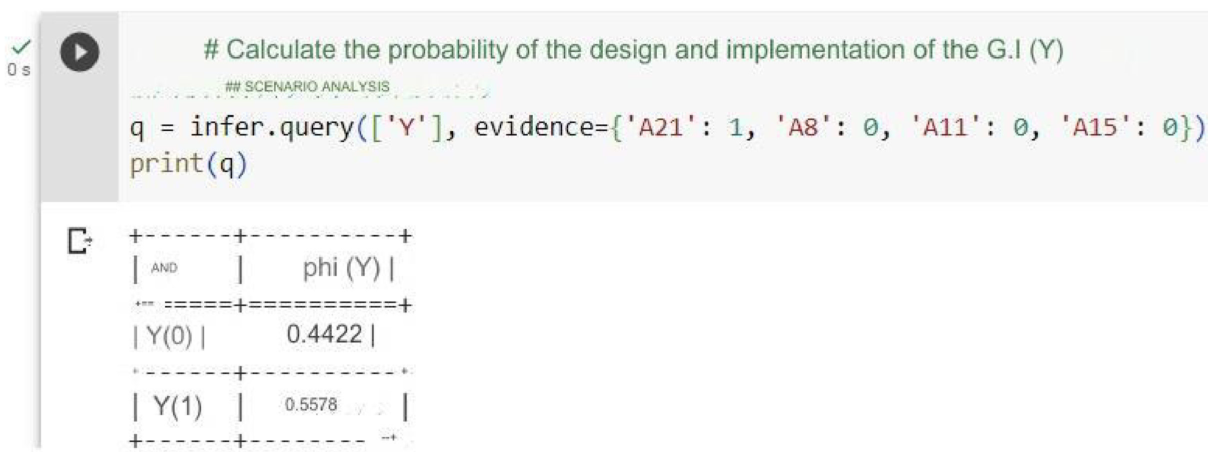


```
# Calculate the probability of the design and implementation of the G.I (Y)
## SCENARIO ANALYSIS
q = infer.query(['Y'), evidence={'A2': 1, 'A4': 1, 'A2': 1, 'A7': 1})
print(q)

+------+----------+
| AND  | phi (Y) |
+======+==========+
| Y(0) |   0.0307 |
+------+----------+
| Y(1) |   0.9693 |
```

Source: Authors’ own elaboration.

Figure 6. Scenarios for variables A21, A8, A11, A15 with respect to Y



```
# Calculate the probability of the design and implementation of the G.I (Y)
## SCENARIO ANALYSIS
q = infer.query(['Y'], evidence={'A21': 1, 'A8': 0, 'A11': 0, 'A15': 0})
print(q)

+------+----------+
| AND  |  phi (Y) |
+======+==========+
| Y(0) |   0.4422 |
+------+----------+
| Y(1) |   0.5578 |
+------+----------+
```

Source: Authors’ own elaboration.

in the literature on the subject. However, as previously stated, the research by Sosa *et al.* (2024) identifies a knowledge gap in the business sector, as it is one of the factors that is least exploited in terms of innovation.

Figure 5 illustrates that modifying the status of variables A4 and A7, equating it to that assigned by the respondents to variable A2, results in an increase in their influence on variable Y with a 96.93% probability of occurrence. This is not the case with the inverse modification. When none of the aforementioned dependent variables is present, the probability of its incidence on Y is reduced to 50%.

It can be observed that the combination of documentation or recording of the IM process and its results (A2), the organisation’s information systems for innovation (A4) and the design and implementation of benchmarking (A7) has a greater influence on IM performance than when each is used independently. This supports the discussion on the interrelationships between the components of ICM and their influence on the enhancement of IM.

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Figure 7. Scenarios for variables A21, A8, A11, A15 with respect to Y

```
# Calculate the probability of the design and implementation of the G.I (Y)
## SCENARIO ANALYSIS
q = infer.query(['Y'], evidence={'A21': 1, 'A8': 1, 'A11': 1, 'A15': 1})
print(q)

+------+----------+
| AND  |   phi (Y) |
+=====+==========+
| Y(0) |   0.2258 |
+------+----------+
| Y(1) | 0.7742
+------+----------+
```

Source: Authors' own elaboration.

Figure 6 presents a statistical analysis of the potential outcomes resulting from the interaction of variables A8, A11, A15 and A21 with GI. It can be observed that the probability of their occurrence on Y is significantly influenced by the presence of variable A21, reaching a value of 55.78%. In contrast, the remaining variables only contribute to a 50% probability of their occurrence on GI.

The preceding results demonstrate that, despite the establishment of spaces for exchange (A8), databases of external and internal experts with channels for them to interact (A11), and a system of lessons learned (A15), the organisation's links with other entities (A21) exert the greatest influence on the probabilistic behaviour of the IG. Therefore, it can be concluded that they are crucial for the generation of knowledge in terms of innovative results. The findings of Trzeciak *et al.* (2022) support the assertion that collaboration with external stakeholders represents a pivotal factor in the success of open business innovation.

Figure 7 illustrates the impact of modifying the status of the group of variables A21, A8, A11 and A15 to consider them as present in the IG. This leads to an increase in the probability of their impact on the latter, rising from 50% to 77.42%. Conversely, when the modification is the other way around and none is considered to be present, the aforementioned probability is reduced to 50%.

The aforementioned result demonstrates that the creation of spaces for exchange (A8), the construction of databases of external and internal experts with channels for interaction (A11), the consolidation of the lessons learned system (A15) and the fostering of the organisation's links with other entities (A21) are all more likely to influence the behaviour of IM than when each is used independently. This serves to confirm the interrelationship between the components of ICDM and their influence and impact on the improvement of IM.

The construction of scenarios with the dependent variables A19, A20, A22, A23 and A24 (Figure 8) revealed that, in their various combinations, only A20 increases the probability of impact on the variable (Y) to 98.9%. The remaining variables do so by 50%. It can therefore be concluded that, even if the plan or strategy of IG is used (A19), the training programme is designed (A22), the legislation referring to the different modalities of industrial property is observed (A23) and methods of monitoring and evaluation of performance in the development of IG are applied (A24), it is the leadership in innovation activities (A20) that most influences probabilistically the behaviour of this one. As Sosa *et al.,* (2024) posit, leadership represents one of the nodes or factors that are strongly related to innovation management.

In this group of variables, the value of the

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Figure 8. Scenarios of variables A19, A20, A22, A23, A24 with respect to Y

```
# Calculate the probability of the design and implementation of the G.I (Y)
    ## SCENARIO ANALYSIS
q = infer.query(['Y'], evidence={'A19': 0, 'A20': 1, 'A22': 0, 'A23': 0, 'A24': 0})
print(q)

+------+----------+
| AND  |  phi (Y) |
+======+==========+
| Y(0) |   0.0113 |
+------+----------+
| Y(1) |   0.9887 |
+------+----------+
```

Source: Authors' own elaboration.

Figure 9. Scenarios of variables A19, A20, A22, A23, A24 with respect to Y

```
# Calculate the probability of the design and implementation of the G.I (Y)
    ## SCENARIO ANALYSIS
q = infer.query(['Y'], evidence={'A19': 1, 'A20': 1, 'A22': 1, 'A23': 1, 'A24': 1})
print(q)

+------+----------+
| AND  |  phi (Y) |
+======+==========+
| Y(0) |   0.0015 |
+------+----------+
| Y(1) |   0.9985 |
+------+----------+
```

Source: Authors' own elaboration.

variable (Y) is found to increase to 99.85% if all are considered to be present in the IG and decrease to 50% when the opposite criterion is adopted and it is considered that these independent variables do not exist.

The aforementioned results demonstrate that when the design of the management plan or strategy (A19), the training program (A22), the various forms of industrial property (A23), the methods for monitoring and evaluating performance in the development of management (A24) and the leadership of innovation activities (A20) are managed in a coordinated manner, their influence on the behaviour of management is greater than when each is used independently. This corroborates previous statements.

This constitutes a valuable result for this research as it confirms that the components of IM itself are the ones that have the greatest impact on its improvement. Even the research carried out by Sosa *et al.,* (2024) corroborates such a result, since leadership, strategic planning, continuous improvement, monitoring, control, and evaluation are identified among the nodes (factors) that have greater strength (relationship) with innovation.

In summary, the above considerations indicate that the resulting variables are identified as impact factors for IM in Cuban state companies, when analysed in combination with both independent variables and groups of variables.

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5. Conclusions

The findings of the literature review and the implementation of the BR model in Cuban SOEs led to the following conclusions:

The components of ICMM, or factors, as managerial processes, in their continuous interrelation, have an impact on the increase and improvement of IM.

The tendency to increase and improve the GI is manifested when several interrelated factors of the GDIC are used at the same time instead of as independent factors.

The ICMM factors with the greatest impact on IM are leadership, the documentation or recording of processes and their results, and the organisation's linkages with other entities.

The most significant factors influencing management are those related to the management plan or strategy, leadership, brand registration, patents and methods for monitoring and evaluating management performance (group 1). The second group encompasses systems within the organisation, as well as the design and implementation of benchmarking. The third group encompasses links between the organisation and other entities, the creation of spaces for exchange, the establishment of a database of experts with channels for them to interact, and systems of lessons learned.

The identification of the impact factors of IM provides various benefits to Cuban state-owned enterprises. Such data can be used to inform decision-making, identify opportunities for innovation and new ideas, and allocate resources more efficiently and effectively to foster creativity. In short, the provision of valuable information enhances the ability of organisations to innovate, adapt and grow in a dynamic business environment.

The principal limitation of this research was the inability to collaborate with companies from other provinces of the country. The potential for collaboration with these entities could have yielded insights not considered in this research. Conversely, the findings may serve as a foundation for a more comprehensive qualitative inquiry to examine the most effective means of integrating the components of ICBM into the management of Cuban state-owned enterprises.

6. Conflict of interest

The authors declare that they have no conflicts of interest.

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