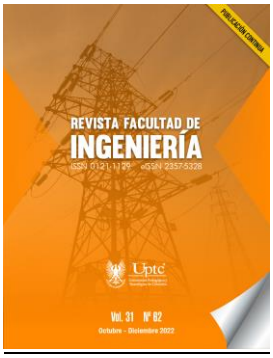
Revista Facultad de Ingeniería
Journal Homepage: https://revistas.uptc.edu.co/index.php/ingenieria



Adaptable Data Warehouse Based on the Research Factor of the NAC Institutional Accreditation Model

David-Antonio Fuentes-Vargas[1]
Martha-Eliana Mendoza-Becerra[2]
Luis-Carlos Gómez-Flórez[3]

Received: September 8, 2022 **Accepted:** December 24, 2022 **Published:** December 31, 2022

Citation: D.-A. Fuentes-Vargas, M.-E. Mendoza-Becerra, L.-C. Gómez-Flórez, "Adaptable Data Warehouse Based on the Research Factor of the NAC Institutional Accreditation Model," *Revista Facultad de Ingeniería*, vol. 31 (62), e15211, 2022. https://doi.org/10.19053/01211129.v31.n62.2022.15211

Abstract

One of the main challenges of higher education institutions is continuously improving educational quality. In Colombia, the National Accreditation Council is in charge of evaluating if an institution provides high-quality education. One of the

[1] M. Sc. (c) Universidad Industrial de Santander (Bucaramanga-Santander, Colombia). david2188757@correo.uis.edu.co. ORCID: 0000-0002-1054-7208
[2] Ph. D. Universidad del Cauca (Popayán-Cauca, Colombia). mmendoza@unicauca.edu.co. ORCID: 0000-0003-4033-2934
[3] M. Sc. Universidad Industrial de Santander (Bucaramanga-Santander, Colombia). lcgomezf@uis.edu.co. ORCID: 0000-0002-5162-5954

stages in obtaining recognition of high quality requires submitting a self-assessment report with quantitative data by the institution. This stage is very demanding for the institutions because it requires handling data extracted from various sources. Data warehouses are an alternative solution since they allow information from various sources to be centralized and support decision-making. This article proposes dimensional models adaptable to the availability of information sources for institutions and focuses on investigative processes. The research methodology used is the Iterative Research Pattern, where the problem was observed through the review of related studies and self-assessment reports submitted to the National Accreditation Council by public institutions. Subsequently, the requirements of the model were created and validated by a group of experts in institutional quality accreditation. Then, the solution was developed, and six adaptable dimensional research models were proposed using the MiPymes methodology, which is validated through a focus group of experts in dimensional modeling of data warehouses that considered the degree of adaptability of the models is 100% to the identified requirements.

Keywords: data warehouses; dimensional modeling; higher education; quality guidelines; research.

Bodega de datos adaptable con base en el factor de investigación del modelo de acreditación institucional del CNA

Resumen

Uno de los principales desafíos de las instituciones de educación superior es mejorar continuamente la calidad educativa. En Colombia, el Consejo Nacional de Acreditación se encarga de evaluar si una institución está brindando educación de alta calidad. Una de las etapas para obtener el reconocimiento de alta calidad requiere la presentación de un informe de autoevaluación con datos cuantitativos por parte de la institución. Esta etapa es muy exigente para las instituciones porque require el manejo de datos extraídos de diversas fuentes. Las bodegas de datos son una solución alternativa ya que permiten centralizar información de diversas fuentes y apoyar la toma de decisiones. Este artículo propone modelos

dimensionales adaptables a la disponibilidad de fuentes de información para las instituciones y se enfoca en los procesos investigativos. La metodología de investigación utilizada es el Patrón de Investigación Iterativa, donde se observó el problema a través de la revisión de estudios relacionados e informes de autoevaluación presentados al Consejo Nacional de Acreditación por instituciones públicas. Posteriormente, los requisitos del modelo fueron creados y validados por un grupo de expertos en acreditación de calidad institucional. Luego se desarrolló la solución y se propusieron seis modelos de investigación dimensional adaptables utilizando la metodología MiPymes, los cuales son validados a través de un grupo focal de expertos en modelado dimensional de bodegas de datos que consider que el grado de adaptabilidad de los modelos a los requerimientos es del 100%.

Palabras clave: bodegas de datos; modelado dimensional; educación superior; lineamientos de calidad; investigación.

Data warehouse adaptável com base no fator de pesquisa do modelo de acreditação institucional CAN

Resumo

Um dos principais desafios das instituições de ensino superior é melhorar continuamente a qualidade educacional. Na Colômbia, o Conselho Nacional de Acreditação é responsável por avaliar se uma instituição está oferecendo educação de alta qualidade. Uma das etapas para obter o reconhecimento de alta qualidade exige a apresentação de um relatório de autoavaliação com dados quantitativos por parte da instituição. Esta etapa é muito exigente para as instituições porque requer a gestão de dados extraídos de várias fontes. Os data warehouses são uma solução alternativa, pois permitem centralizar informações de diversas fontes e apoiar a tomada de decisão. Este artigo propõe modelos dimensionais adaptáveis à disponibilidade de fontes de informação para instituições e tem como foco processos investigativos. A metodologia de pesquisa utilizada é o Padrão de Pesquisa Iterativa, onde o problema foi observado por meio da revisão de estudos relacionados e relatórios de autoavaliação enviados ao Conselho Nacional de Acreditação por instituições públicas. Posteriormente, os

requisitos do modelo foram elaborados e validados por um grupo de especialistas em acreditação de qualidade institucional. Em seguida, desenvolveu-se a solução e propuseram-se seis modelos dimensionais adaptáveis de pesquisa utilizando a metodologia MiPymes, os quais são validados através de um grupo focal de especialistas em modelagem dimensional de data warehouses que consideraram que o grau de adaptabilidade dos modelos aos requisitos é de 100%.

Palavras-chave: data warehouses; modelagem dimensional; educação superior; diretrizes de qualidade; pesquisa.

I. INTRODUCTION

Higher Education Institutions (HEIs) must continuously monitor the quality of the service provided to their students. The National Accreditation Council (NAC) is the Colombian entity in charge of establishing whether or not HEIs that undergo evaluation carry out their functions with high quality. The NAC evaluates institutions based on twelve factors contained in Agreement 03 of 2014 [1]. One of these refers to the research processes carried out by the institution, which include such activities as internal and external funding calls, groups, seedbeds and research projects. One of the steps in the process of receiving the high-quality recognition consists of the institution submitting a self-assessment report with quantitative data for each factor. In most cases, this is a task that can last months since it involves collecting and centralizing data from different sources and is done almost manually by a group selected from teaching staff that make up the accreditation committee or the Accreditation Office [2].

Data warehouses (DW) offer an alternative solution for this type of process. A DW allows the centralization of information from various sources (relational databases, EXCEL files, etc.) [3]. A DW further supports decision-making using reports showing graphs that present the data generally and then in more detail, depending on the need of the data analyst. This would allow HEIs to make decisions to improve on shortcomings detected in the data [4]-[5].

This work was carried out using the Iterative Research Pattern (IRP) methodology, wherein the first stage, the *Observation* stage, DW articles at the national level [6] were identified for funding calls, groups, seedbeds and research projects, and at the international level [7]-[12], DW articles that include publications, projects and research funding. The robustness of the models found in the literature was also identified, comparing the number of dimensions and attributes presented with those identified in the NAC requirements.

The second stage consists of *Problem identification*. For this, the related articles were analyzed to identify possible dimensions and measures, and the self-assessment reports presented by some of the public HEIs to the NAC were reviewed. In addition, a group of experts in institutional accreditation from NAC

validated the analytical requirements arising from this stage.

The third stage is *Solution development*, for which the MiPymes (MBD) methodology [13] was used to design the proposed dimensional models based on the requirements of the previous stage. These models can be adapted to the context of each institution since they consider elements that meet the requirements most frequently used by public HEIs in self-assessment reports, elements of the least frequent requirements (if the institution has a sufficient amount of information), and additional requirements proposed by the authors and experts in accreditation that comply with the aspects to be evaluated by the NAC. The models proposed in this work are therefore adapted to the availability of data from the HEI.

The last stage is *Solution testing*, addressed using a focus group of DW modeling experts who validated the proposed models according to a test that measures the adaptability of these models to the requirements identified by the authors and the experts in accreditation.

This article first presents the research methodology used. Next, a description of the six models obtained with a validation carried out by three modeling experts through a focus group, and finally, the conclusions and future work.

II. METHODOLOGY

This study uses the Iterative Research Pattern (IRP) proposed by [14], a methodology for research projects that involves computational solutions. According to [14], cycles made up of stages must be defined: observation, problem identification, solution development and solution testing. In each cycle, a product must be delivered.

In this case, a cycle was defined for the design of the proposed dimensional models adaptable to the investigative processes of an HEI based on the institutional accreditation research factor of the National Accreditation Council (NAC) in Colombia [15].

A. Observation

1) Literature Review. A literature review is carried out to understand how the DW for HEIs focused on research areas is modeled. The planning proposed by [16] is used, which consists of:

Objective: to define a set of dimensional models on research that is consistent with the factor of research of the NAC high-quality accreditation.

Resources: ACM Digital Library, IEEE Xplore, Science Direct, Scopus, Springer Link, and Web of Knowledge databases.

Research question: Q1: What dimensional modeling elements have been related to the factor of research processes?; Q2: What design situations used for research processes could be incorporated into the proposed model?

Search string: (dimension* model* OR design) **AND** (business intelligence OR data warehouse*) **AND** (educat* OR high* educat* OR academic*) **AND** (research* or investigation)

Inclusion/exclusion criteria: The criterion for including a candidate study was that the study must NOT have been published before 2014.

The criteria for excluding a candidate study were as follows: (1) The study is NOT relevant to the development of Data Warehouses (DW) for higher education; (2) The study does NOT present a dimensional model related to research.

The search string was applied to previously established databases, finding seven articles that met the inclusion/exclusion criteria.

2) Analysis of the Studies. In 2014, [7] proposed DW models, dashboards, and the use of data mining for HEIs, presenting a *Publications* star diagram whose dimensions are Program, Professor, and Publication Type. In addition to, *Research*, in which the dimensions are Research Category, Lead Researcher, Academic Position and Period of Research Activity. The resulting dashboards and models do not present design situations or validation mechanisms.

In 2015, [8] defined the architecture of a Business Intelligence system for academic organizations, showing a *Publication* model with the dimensions Publisher, Typology, Year, Author, Academic Unit, Knowledge Area, Department, and Institutional Role of the Author. This model uses many-to-many dimensions and

sub-dimensions but does not have validation mechanisms.

In 2017, [9] proposed a DW for the measurement of disciplinary development in library and information sciences in academic institutions. The proposed *Projects* model presents design cases as sub-dimensions and many-to-many dimensions. It presents the dimensions: Participants, Financing, Area of Knowledge, Responsible for the Project, Project Status, and Participating Institution. No model validation mechanism is mentioned.

In 2018 [10], proposed a research information system to analyze bibliometric indicators. Sub-dimensions are used as design cases. The *Publications* model presents the dimensions Author, Indexing in Scopus and Web of Science, Department, and Citation Metrics. The model is not validated within the study.

In this same year, [11] described the development of a multidimensional model with two models, *Publications* and *Projects*. The indicators managed by the study consist of Number of Publications and Projects. The dimensions handled in the model are Time, Study Level, Research Activity, Area of Knowledge, Type of Project, Project Status, Type of Publication, and Category of Hiring of Professors. Design cases are not presented, nor is the proposed model validated.

Regarding gray literature, also in 2018 [12], a DW was built for financial data and their visualization tool. No design cases were presented in the star diagram. The *Financing* model handles the Fund, Financial Unit, Account, and Time dimensions. The resulting model was not validated by experts, but a query performance test and a usability test were carried out with five users.

Another study of gray literature was developed in 2022 [6], which designs dimensional models for *Funding calls*, *Groups*, *Seedbeds,* and *Research Projects*. The models handle design cases: role-playing, many-to-many, and degenerate dimensions. The models use the conformed dimensions: Project, Group, Person, Date, and Project Status. The *Project* model contains the dimensions: Project documents, Funding call and the Participants bridge tables, Research line, and Members; the Financing model contemplates the dimensions: Item, Financial Entity, Type of Financing, and the bridge table Type of Expenditure; the *Group* model presents the Discipline, Ranking, Group Location dimensions, and the bridge

Project; the model *Seedbed* with the Integrating Role, Work Plan, Seedbed Documents, Status, and Program. Regarding validation, this study evaluated the level of satisfaction of officials of the research division of the HEI.

Table 1 summarizes the models found in the review, taking into account the use of design situations (Des. Sit.), the evaluation of the result (Eval.), the analysis capacity of the models measured in the number of dimensions and attributes, and measures.

Table 1. Synthesis of the literature related to DW for research in HEI.

Ref. Year	Model	Des. Sit.	Eval.	Analysis capacity of (Dimensions and attributes)	Measures
[6] 2014	Publications and Research	No	No	Few dimensions.	Number of publication and research activities.
[7] 2015	Publications	Yes	No	Few dimensions and very few attributes.	Number of publications.
[8] 2017	Projects	Yes	No	No attributes.	Number of research projects.
[9] 2018	Publications	Yes	No	Few dimensions and few attributes.	Number of publications.
[10] 2018	Publications and Projects	No	No	Few dimensions and no attributes.	Number of publications and research projects.
[11] 2018	Financing	No	Yes	Few dimensions.	Financial amount.
[6] 2022	Projects, Financing, Groups, Seedbeds	Yes	Yes	Handles a greater number of dimensions and attributes.	Funding value and the number of projects, groups, and seedbeds.

As can be seen in Table 1, most of the models found in the literature (57.14%) are related to Publications, three deal with issues related to Projects, and two contain models for Financing, Research Groups, and Seedbeds. 57.14% of these models handle design situations such as several-to-many dimensions, sub-dimensions and role play. Regarding the evaluation of the models, only 28.57% of the studies carried out some external consultation that will validate the model or the proposed implementation, showing the need to create studies that validate the results presented.

Although the dimensions, attributes and measurements of the studies found can be

taken as a basis for the construction of the dimensional models of the present study, in Table 1, it can be observed that most of the dimensional models of these studies present few dimensions, attributes, and measures. This limits their analysis capacity. Furthermore, none of the models mentions the use of a quality assurance model.

3) NAC Institutional Accreditation Model. The *Research and artistic and cultural creation* factor of the institutional accreditation model and the eighteen available self-assessment reports presented by public HEIs that have participated in high-quality accreditation processes of the NAC were reviewed. The aim was to identify the aspects to be evaluated that were found to contain quantitative data within the reports, which are shown underlined in Table 2.

Table 2. Aspects to evaluate of the NAC research and cultural and artistic creation factor.

Characteristic	Aspects to evaluate	
Training	1. Policies and strategies. 2. The commitment to the construction of knowledge. 3. Institutional support.	4. Elements of curricular flexibility. 5. Facilities for participation. 6. Actions to improve the policies and strategies developed.
Research	1. Quality of the research infrastructure. 2. Researcher training level. 3. Degree of development of research units. 4. Stability of research units. 5. Criteria for allocating time to research. 6. Publications as result of research. 7. Recognition of artistic and cultural creation. 8. Awards and distinctions.	9. Administrative and financial support. 10. Ability to manage external resources. 11. Existence of intellectual property regime. 12. Academic production evaluation mechanisms. 13. Researchers recognized by MinCiencias (governmental entity in charge of promoting research and innovation capacities [32]). 14. Postgraduate students graduated.

B. Problem Identification

The requirements for the modeling of a DW for investigative processes in HEIs are defined, taking into account the aspects to be evaluated underlined in Table 2, the eighteen institutional self-assessment reports of public HEIs, and the results of the review of the state of the art.

The requirements were divided into three categories taking into account the occurrence in the self-assessment reports: *most frequent*, repeated in more than five; *least frequent*, repeated from three to five; and *proposed requirements*, which,

although not mentioned frequently, were suggested by accreditation experts. This division of the requirements seeks to define the adaptability of the models, which can serve both the HEI interested in only the most frequent requirements and the one that wants to use a more extensive version of the dimensional model. The choice will depend on the provisions internal to the institution and the availability of data.

The identified requirements were validated by the group of experts shown in Table 3 (identified as A1, A2 and A3), who reviewed them and made recommendations, allowing the final requirements to be reached.

Table 3. Experts in NAC quality accreditation processes.

Expert ID	Occupation	Studies	Experience
A1	Academic quality assessment coordination –Universidad Industrial de Santander.	PhD in telecommunications engineering.	Five (5) years of experience as a NAC counselor at the national level.
A2	Academic quality assessment coordination – Universidad Industrial de Santander.	Systems engineer.	More than ten (10) years of experience in Educational Quality Assessment.
A3	On-staff lecturer - Universidad Industrial de Santander.	PhD in technological innovation management	More than ten (10) years of experience in program and institutional accreditation.

C. Solution Development

The design of the DW model was carried out using the data warehouse development methodology for MiPymes (MBD) [13], which is characterized by an iterative and incremental approach, user participation and detailed phases. It is pertinent to use this methodology because it is designed for small workgroups, handling a few roles and artifacts.

The work cycle used is made up of the following phases: (1) Initiation: the set of research processes to be modeled is selected; (2) Planning: the work plan for the design of the selected research processes is defined; (3) Analysis and design: based on the requirements extracted from the NAC research factor, self-assessment reports, and the dimensions and attributes identified in the state of the art, the DW models proposed for HEIs were designed.

In the *Observation* stage previously detailed, a review that serves as a starting point

in the *Initiation* phase of the MBD methodology [13] was carried out, and the business processes with the greatest viability and impact were identified. With this input, the *Planning* stage begins, in which the implementation of the models is justified based on the data collection problems arising in the accreditation processes. Subsequently, the third stage is applied, called *Analysis and Design*, which begins with the *Requirement Gathering* subphase, carried out based on the design elements identified in the review, the aspects to be evaluated using Agreement 03 of 2014 [1], and the opinion of experts in institutional accreditation. The second subphase of this stage is *Design*, where the attributes of the data warehouse are preliminarily defined, specifying whether they are primary or foreign keys. At the end of this subphase, the review and user acceptance activity is carried out, in which a group of DW modeling experts reviews and qualifies the dimensional modeling performed. The subsequent stages proposed in the MDB methodology are *Development*, *Maintenance* and *Growth*, and *Project Management*. These last three phases are not part of the scope of the study and are proposed as future work.

D. Solution Testing

Validation of the dimensional models is carried out through a focus group of experts in DW modeling (identified as M1, M2 and M3), detailed in Table 4.

Table 4. Experts in DW modeling.

ID	Occupation	Studies	Experience
M1	DW lecturer – University of Magdalena.	PhD in computer science.	More than five (5) years of experience in dimensional modeling of DW projects. M2
M2	DW lecturer – National University of Colombia.	PhD in computer science.	
M3	Data Architect – PRAGMA S.A.	Master in data science.	

Reading material containing details of the dimensional models was sent to the experts by email prior to conducting the focus group. In the course of the focus group, a presentation of these models was made, and the experts had a space for feedback. Finally, they filled out the questionnaire in Table 5, evaluating the models based on the sub-characteristic of adaptability of the ISO/IEC 25010 standard [17].

Table 5. DW expert assessment questionnaire questions.

ID	***Closed questions***
1	Do you consider that the dimensional model proposed for this factor is adapted to the requirements that are most frequently repeated in accreditation reports?
2	Do you consider that the dimensional model proposed for this factor is adapted to the requirements that are least frequently repeated in accreditation reports?
3	Do you consider that the dimensional model proposed for this factor is adapted to the requirements proposed by the author and the experts in institutional accreditation?
4	4 Do you consider that the model supports institutional strategic decision-making?
ID	***Open questions***
5	Do you think other elements should be added to the dimensional model presented? If so, which ones and why?
6	Do you consider that some elements of the dimensional model presented should be eliminated? If so, which ones and why?
7	Do you consider that some elements of the dimensional model presented should be modified? If so, which ones and why?
8	Do you have any additional comments about the dimensional model?

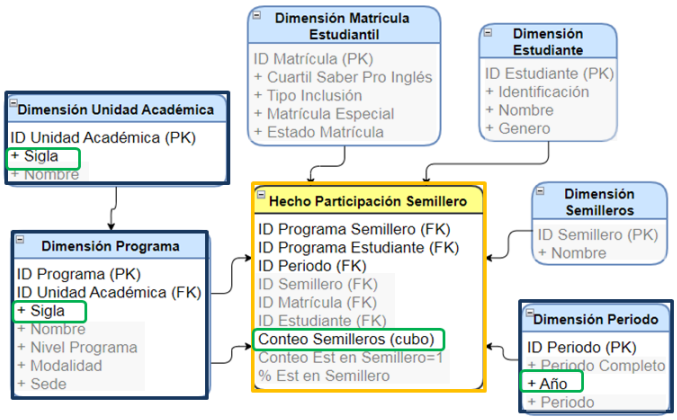
III. RESULTS

This section presents the six adaptable dimensional models proposed based on the Research factor of the NAC for HEIs, and their validation through a focus group.

A. Dimensional Models

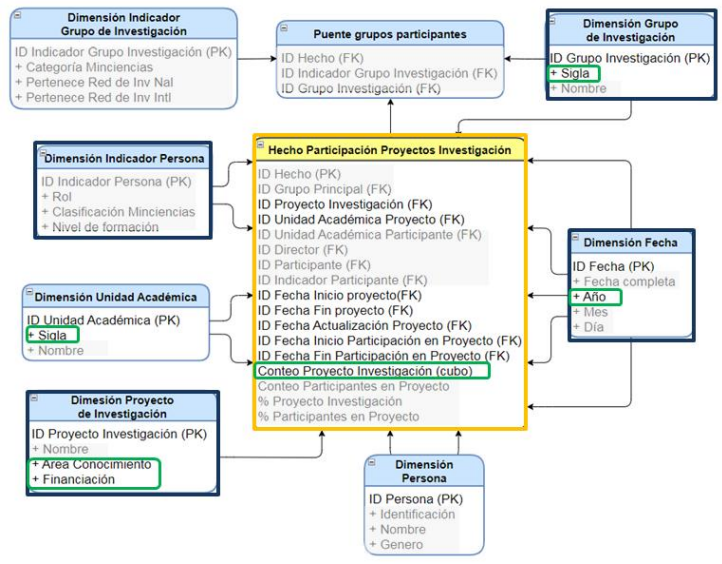
In Tables 6 to 11, the six proposed adaptable dimensional models are presented, together with the requirements. The measures and attributes that are in gray comply with the least frequent and proposed requirements. The measurements and attributes in black correspond to the most frequent requirements. This distinction is made to show the model's adaptability, allowing that if an HEI wants to consider only the most frequent requirements, it can use only the measures and attributes in black. The dimensional model of *Participation in Seedbed* (See Table 6) presents a role play in *Program* due to the possibility that a student from a program may belong to a seedbed of another program. The sub-dimension *Academic Unit* is also used, which will be used in the requirements of other models. In the model as an example, the attributes and the measure of the most frequent requirement are presented in a green box.

Table 6. Requirements and model of *Participation in Seedbed.*

Requirements	Dimensional model
Most frequent: number of seedbeds per program, academic unit, and year. ***Least frequent***: number of students in seedbeds per academic unit and year. ***Proposed***: percentage of students in seedbeds by academic unit and year.	

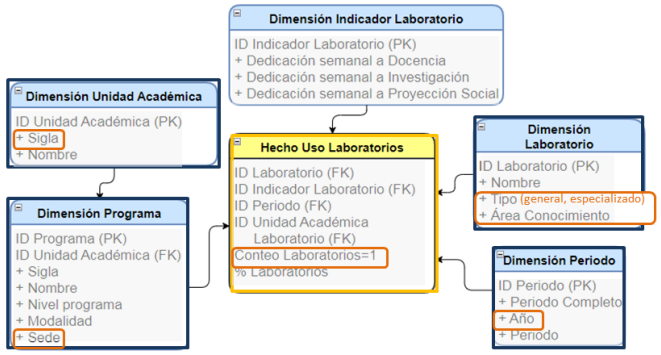
The model of *Participation in Research Projects* (**¡Error! La autoreferencia al marcador no es válida.**) presents a role play in *Academic Unit*, *Person*, and *Person* and *Date Indicator* due to attributes that can correspond to both the project and its participant, the many-to-many of participating groups dimension is also used, which manages both the *Research Group Indicator* dimension (a mini-dimension) and *Research Group*. In a similar way to the *Seedbed Participation* model, the most frequent requirement is presented with the attributes and the measure in a green box.

Table 7. Requirements and model of *Participation in Research Projects*.

Requirement	Dimensional model
Most frequent: number of research projects by research group, area of knowledge, funding, academic unit and year. ***Proposed***: number and percentage of students in research projects by research group, area of knowledge, funding, academic unit, and year. Percentage of research projects with students by research group, area of knowledge, funding, academic unit, and year.	

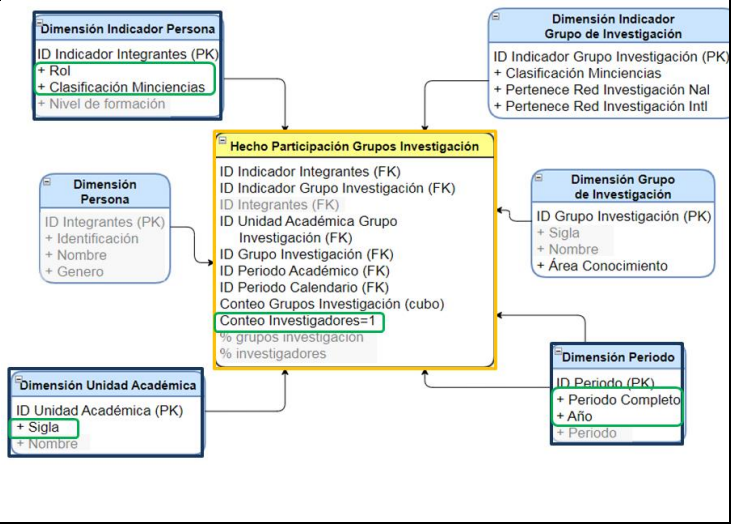
In the *Use of Laboratory* model (Table 8), all the attributes and measures of the model are gray because there were no more frequent requirements for this model. Therefore, the attributes and the measure of the first requirement (least common) are in an orange box.

Table 8. Requirements and model of *Use of Laboratories.*

Requirement	Dimensional model
Least frequent: number of general and specialized laboratories by academic unit, area of knowledge, location, and year. ***Proposed***: percentage of general and specialized laboratories by academic unit, area of knowledge, location, and year.	

In the dimensional model of *Participation in Research Groups* (See **¡Error! La autoreferencia al marcador no es válida.**), a role play is handled for the *Period* dimension due to the existence of an academic period and a calendar period. The attributes and the measure of the first requirement are also shown in a green box.

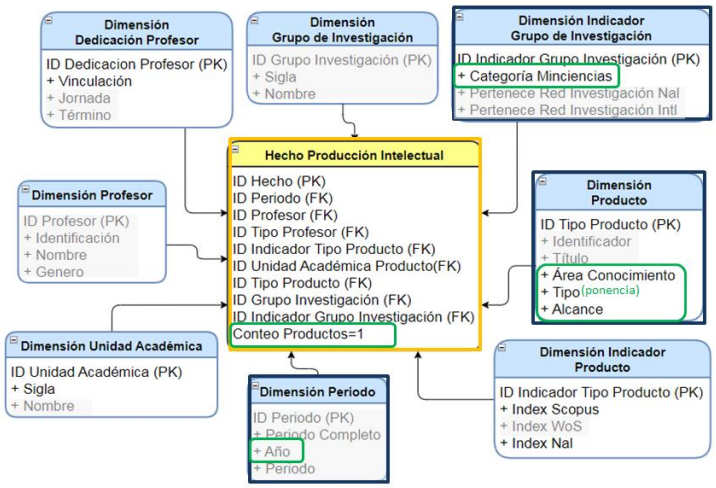
Table 9. Requirements and model of *Participation in Research Groups.*

Requirement	Dimensional model
Most frequent: number of researchers by classification in Minciencias, role, academic unit, period, and year. Number of research groups by category in Science by belonging to a national and international network, Academic unit, area of knowledge, and year. ***Proposed***: percentage of researchers by classification in Minciencias, role, academic unit, period, and year. Percentage of research groups by category in Science by belonging to a national and international network, academic unit, area of	

knowledge, and year.	

The dimensional model of *Intellectual Production* (
Table 10) has the attributes and the measure of the most frequent requirement indicated in a green box.

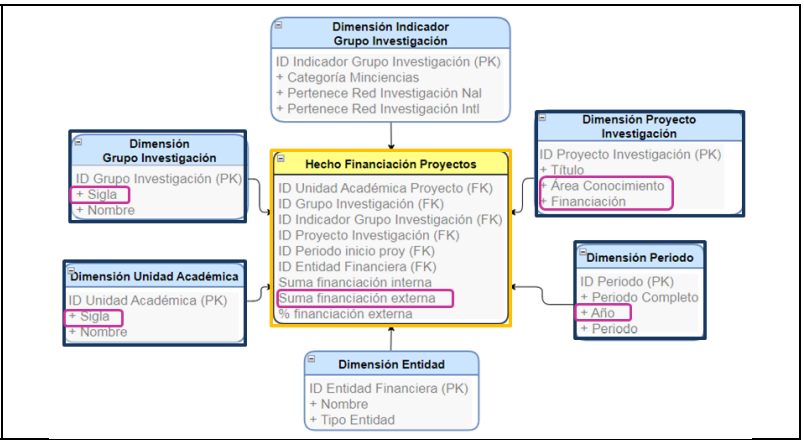
Table 10. Requirements and model of *Intellectual Production.*

Requirement	Dimensional model
Most frequent: number of teaching papers by scope, articles by scope of full-time professors by indexing category, books, publications in Scopus, software and book chapter by category of research group, area of knowledge, academic unit, and year. ***Least frequent***: number of translations by professors, national and international patents by tenured professors, artistic works, publications on the Web of Science, and professor's master's and doctoral works by research group, according to category, academic unit, and year. ***Proposed***: number of essay books, postdoctoral studies (9, 10, 11, or 12 months), and critical reviews by journal category by year.	

The *Project Financing* dimensional model (**¡Error! La autoreferencia al marcador no es válida.**) presents the attributes and the measure in a purple box because they correspond to a proposed requirement.

Table 11. Requirements and model of *Project Financing.*

Requirement	Dimensional model

Proposals: value in Colombian pesos of external resources for research destined to research projects by research group, area of knowledge, funding, academic unit, and year.	

B. Validation of the Dimensional Models

The validation of the proposed models was carried out through a focus group of experts presented in **¡Error! No se encuentra el origen de la referencia.** and using the closed questions in Table 5, obtaining the results shown in Figure 1, where the number of experts who responded at each level of the Likert scale is shown.

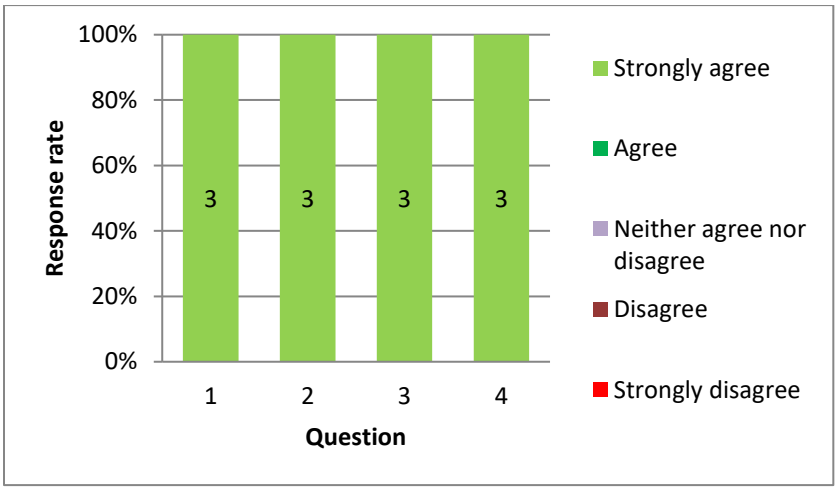


Fig. 1. Responses to closed questions.

For the group of experts, the proposed models are 100% adaptable to the most frequent, least frequent, and proposed requirements identified and can serve as support for strategic decision-making in research areas.

Based on the responses of the experts to the open questions in Table 5, the improvement actions mentioned in Table 12 are carried out in the models.

Table 12. Improvement actions in open questions.

Expert ID	Comment	Improvement Action/Justification
M2	Add publication geography to the intellectual production fact table.	The *Location* dimension is added within the model of Table 10.
M3	Bear in mind that percentage measures have performance flaws when making a query for large amounts of data.	In the deployment stage, the performance of the queries must be measured and it must be determined whether it is necessary to generate aggregations in the cube or indexes in the relational database.
	The bridge table of project participants has measures. It is recommended to handle it as a fact table.	The bridge table of participants is eliminated. The measure of the number of participants in the project that was contained in the bridge dimension is transferred to the fact table in The model of *Participation in Research Projects* (**¡Error! La autoreferencia al marcador no es válida.**) presents a role play in *Academic Unit*, *Person*, and *Person* and *Date Indicator* due to attributes that can correspond to both the project and its participant, the many-to-many of participating groups dimension is also used, which manages both the *Research Group Indicator* dimension (a mini-dimension) and *Research Group*. In a similar way to the *Seedbed Participation* model, the most frequent requirement is presented with the attributes and the measure in a green box. Table 7. In this way, the granularity remains by participants, and the number of projects can be consulted using a Distinct defined in the OLAP cube.
	The use of the many-to-many "Bridges" tables could be studied in depth since, in the future, it would be a relationship between tables with too many records.	The use of many-to-many dimensions in the models is avoided, only the bridge table of research groups is maintained in the research projects model in Table 7 since the research groups do not present changes with high frequency.

IV. Conclusions

The dimensional models of research in HEIs focus mainly on publications and research projects, which are built based on the needs of particular HEIs and do not contemplate high-quality requirements in education. In this article, six adaptable dimensional models are proposed, which take into account the quantitative quality requirements of the research factor for the high-quality accreditation of the NAC, the eighteen self-assessment reports available presented by public HEIs before the

NAC, the dimensions and attributes found in the review of the literature, and the opinion of experts in the accreditation of educational quality.

Of the models found in the literature review, a mere 28.57% of studies went on to evaluate the model through an external consultation that would validate the model or the proposed implementation, revealing a need to create studies that go on to validate their results.

Validation of the proposed adaptable dimensional models was carried out by means of a focus group of experts in dimensional modeling, which found that the models are 100% adaptable to the most frequent, least frequent, and proposed requirements. A group of accreditation experts also validated the requirements. These adaptable models will allow HEIs to appropriate them according to the information available in the different data sources, and they can serve as support for strategic decision-making in research fields.

As future work, it is proposed to address the other quality factors established by the NAC to propose dimensional models adaptable to HEIs to support these factors.

The dimensional models proposed ought to be validated by a broader focus group, that is, with the participation of more HEIs in the country. In addition, it is sought to implement the models through the *Development and Maintenance* and *Growth* stages of the MBD methodology, allowing the generation of the reports requested by the NAC in the *Research and artistic and cultural creation* factor in a self-assessment process for institutional accreditation.

FINANCING

Research article derived from the project "Dimensional model for academic, investigative and follow-up processes for graduates in public Higher Education Institutions", partially financed by the Universidad Industrial de Santander and the Universidad del Cauca.

AUTHORS' CONTRIBUTION

David-Antonio Fuentes-Vargas: research, validation, writing – original draft..

Martha-Eliana Mendoza-Becerra: conceptualization, supervision, research, writing

- review and editing.

Luis-Carlos Gómez-Flórez: supervision, research, writing - review and editing.

REFERENCES

[1] CESU, *Acuerdo 03 de 2014*, Consejo Nacional de Acreditación (NAC). Colombia, p. 32, 2014.

[2] J. E. Martínez, S. Tobón, A. Romero, "Problemáticas relacionadas con la acreditación de la calidad de la educación superior en América Latina," *Innovación Educativa*, vol. 17, no. 73, pp. 79–96, 2017.

[3] G. E. Silva Peñafiel, V. M. Zapata Yánez, K. P. Morales Guamán, L. M. Toaquiza Padilla, "Análisis de metodologías para desarrollar Data Warehouse aplicado a la toma de decisiones," *Ciencia Digital*, vol. 3, no. 3.4., pp. 397–418, 2019. https://doi.org/10.33262/cienciadigital.v3i3.4..922

[4] IBM, *Engineering Lifecycle Management - Data Warehouse*, 2022. https://www.ibm.com/docs/en/elm/6.0?topic=overview-data-warehouse

[5] R. Kimball, M. Ross, *The Data Warehouse Toolkit: The Definitive Guide to Dimensional Modeling*, 3d ed. John Wiley & Sons, Inc., 2013.

[6] W. Camilo, L. Mera, *Modelo Dimensional para Proyectos y Grupos de Investigación de la VRI de la Universidad del Cauca*, Grade Thesis, Universidad del Cauca, 2022.

[7] E. K. A. Miranda, E. L. I. Suryani, "Implementation of Data Warehouse, Data Mining and Dashboard for Higher Education," *Journal of Theoretical and Applied Information Technology*, vol. 64, no. 3, pp. 710–717, 2014.

[8] F. Di Tria, E. Lefons, F. Tangorra, "Academic Data Warehouse Design Using a Hybrid Methodology," *Computer Science and Information Systems*, vol. 12, no. 1, pp. 135–160, 2015. https://doi.org/10.2298/CSIS140325087D

[9] S. Gorbea Portal, M. Madera Jaramillo, "Diseño de un data warehouse para medir el desarrollo disciplinar en instituciones académicas," *Investigación Bibliotecológica*, vol. 31, pp. 161–181, 2017. https://doi.org/10.22201/iibi.0187358xp.2017.72.57828

[10] D. Solodovnikova, L. Niedrite, A. Niedritis, "Architecture Enabling Adaptation of Data Integration Processes for a Research Information System," *Foundations of Computing and Decision Sciences*, vol. 43, no. 2, pp. 129–149, 2018. https://doi.org/10.1515/fcds-2018-0008

[11] F. Medina, F. Fariña, W. Castillo-Rojas, "Data Mart para obtención de indicadores de productividad académica en una universidad Data Mart to obtain indicators of academic productivity in a university," *Ingeniare. Revista Chilena de Ingeniería*, vol. 26, pp. 88–101, 2018. https://doi.org/10.4067/S0718-33052018000500088

[12] E. V. F. Lapura, J. K. J. Fernandez, M. J. K. Pagatpat, D. D. Dinawanao, "Development of a University Financial Data Warehouse and its Visualization Tool," *Procedia Computer Science*, vol. 135, pp. 587–595, 2018. https://doi.org/10.1016/j.procs.2018.08.229

[13] M. E. Mendoza, L. Durán, N. Rivera, "MBD 1.0. Metodología de Desarrollo de Bodegas de Datos Para Micro, Pequeñas y Medianas Empresas," *UIS Ingenierías*, vol. 9, no. 1, pp. 85–101, 2010.

[14] K. S. Pratt, "Design Patterns for Research Methods: Iterative Field Research," *AAAI Spring Symposium: Experimental Design for Real*, no. 1994, pp. 1–7, 2009

[15] Congreso Nacional de Colombia, *Ley 30 de Diciembre 28 de 1992*, 1992.

https://www.mineducacion.gov.co/1621/articles-86437_Archivo_pdf.pdf

[16] B. Kitchenham, P. Brereton, “A systematic review of systematic review process research in software engineering,” *Information and Software Technology*, vol. 55, no. 12, pp. 2049–2075, 2013. https://doi.org/10.1016/j.infsof.2013.07.010

[17] ISO/IEC, *International Standard ISO/IEC 25010*, 2011.