Roadmap for Implementing Business Intelligence Systems in Higher Education Institutions: Validation of a Case Study at the University of Trás-os-Montes and Alto Douro

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Abstract: The adoption of effective policies and access to relevant information are critical to improving strategic management and performance monitoring in Higher Education Institutions (HEIs), which is essential to promote data-driven decision-making. This article describes how an HEI can carry out the validation process when implementing a Business Intelligence (BI) system, and provides a detailed guide to doing so. Through a case study at the University of Trás-os-Montes and Alto Douro, a structured roadmap is validated, which acts as a visual and sequential guide to facilitate the effective implementation of BI solutions. The validation carried out through semi-structured interviews with experts and evaluation of dashboards by user groups, not only confirms the applicability and efficiency of the proposed model but also emphasises its practical relevance, providing valuable insights for the adaptation and use of BI in different educational contexts.

1 INTRODUCTION

Higher Education Institutions (HEIs) face persistent challenges in developing effective strategies and accessing relevant information necessary for monitoring their performance and guiding strategic management in alignment with their specific missions and strategies (Calitz et al., 2018; Nieto et al., 2019; Valdez et al., 2017). Accurate performance assessment and proficient management of Information Technologies (IT) are crucial for translating strategies into effective operational actions and enhancing the overall performance of HEIs (Julianti et al., 2021; Meçe et al., 2020; Vallurupalli & Bose, 2018). Business Intelligence (BI) has emerged as a critical strategic tool that enables the collection, analysis, and retrieval of data to support informed decision-making and meet current performance management needs in higher education (Manuel Mora et al., 2017; Sorour et al., 2020; Yahaya et al., 2019).

The implementation of BI systems in HEIs, however, presents numerous challenges. These include integrating BI systems with existing IT infrastructures, ensuring data quality and consistency, meeting the diverse needs of various stakeholders, and fostering a data-driven culture within the institution (Barbosa et al., 2022; Carvalho et al., 2022; Khashab et al., 2020). Additionally, differences in institutional structures, regulatory environments, and available resources can significantly affect the implementation process (Park et al., 2020; Pikas et al., 2020). Therefore, it is essential to develop and validate a roadmap tailored to the unique context of each institution to effectively guide the implementation of BI systems in HEIs.

This study aims to develop and validate a new roadmap for implementing BI systems within a specific HEI. Contrary to the impression that a roadmap already exists and is ready for

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implementation, this research focuses on the creation and validation of a new roadmap. The proposed roadmap acts as a visual and sequential guide designed to adapt to the varying needs and characteristics of HEIs, thereby facilitating the effective implementation of BI solutions tailored to the specific institutional context (Rauschenberger & Baeza-Yates, 2021; Su et al., 2020).

The core of this research involved validating the proposed roadmap through a case study conducted at the University of Trás-os-Montes and Alto Douro (UTAD). The methodology adopted included semi-structured interviews with experts from the institution and user group evaluations of dashboards to ensure the roadmap's applicability and effectiveness in a real-world context. This iterative validation process highlights the importance of refining and adapting the roadmap based on direct feedback from users and stakeholders, ensuring its practical relevance and usability (Doyle et al., 2016; Fernández-Cejas et al., 2022).

A critical aspect of this validation was the assessment of the dashboards by user groups, which ensured that the dashboards were designed with the needs of end users in mind. This process involved evaluating the usability and relevance of the metrics presented, identifying and resolving any usability issues, and ensuring that the dashboards align with the institution's strategic goals. This user-centric approach underscores the need for continuous feedback and adjustment post-implementation, emphasizing that the implementation of BI solutions in higher education requires a dynamic and adaptive methodology (Apiola & Sutinen, 2021; Su et al., 2020).

In summary, this study not only aims to validate a pre-existing roadmap but also to develop and refine a roadmap that is adaptable to the diverse and complex environments of HEIs. By addressing the unique challenges faced by HEIs in implementing BI systems, this study seeks to provide a comprehensive guide that supports informed decision-making and enhances strategic management across various educational contexts.

This work builds upon previous research by Sequeira et al. (2023), which initially proposed a methodology for developing a BI integration roadmap for HEIs. The primary aim of this study is to extend that research by focusing on the practical implementation and validation of a BI solution at the UTAD, thereby offering a refined and validated roadmap that other HEIs can adopt and adapt.

The structure of this paper is as follows: we begin with an introduction that defines the research problem and highlights the importance and objectives of the study. This is followed by a detailed description of the research methodology. We then discuss the validation of the roadmap, from the theoretical basis to the practical validation process, including the important stage of user group evaluation of the dashboards. The article ends with final reflections on the work and suggestions for future research, culminating with acknowledgements and a list of references that support the study.

2 RESEARCH METHODOLOGY ADOPTED

The scientific field of BI pertains to computer science, specifically within IT. Research methodology in Information Systems (IS) adheres to a structured approach defining the procedures and steps for conducting scientific research. Ragab and Arisha (2017) emphasize that selecting an appropriate research methodology is crucial for successful research, and researchers must understand alternative methods to identify the most suitable for their research question. Pruzan (2016) discusses the scientific method in detail, highlighting experimental design, validation, uncertainty, and statistics, emphasizing the importance of reflecting on the deeper goals of scientific work. Ioannidis (2018) argues that studying research itself is crucial for improving the efficiency and credibility of scientific work.

Research methodology can be defined as a systematic approach to solving research problems that produce credible and useful results. Researchers need to consider their approach carefully to ensure the validity and reliability of their conclusions. Kilani and Kobziev (2016) reinforce the importance of defining an appropriate research methodology, considering both qualitative and quantitative approaches and the use of case studies in IS research.

In this study, we adopted a methodological approach comprising three main components: case study, Design Science Research (DSR), and focus groups. This mixed-methods approach was selected to ensure a comprehensive analysis and validation of the proposed roadmap for BI system implementation in HEIs.

The case study was selected as the primary research method due to its ability to provide an in-depth and contextualized understanding of the phenomenon under study. It involves a detailed analysis of a specific individual, group, organization,

event, or phenomenon within its real-life context, collecting detailed qualitative data (Sutherland, 2016; Turnbull et al., 2021). The case study method is widely used in DSR (Su et al., 2020), which we employed to develop our roadmap. The use of a case study, particularly in an HEI, allows for exploring specific phenomena in a particular context, offering versatile application forms depending on the research focus and objectives (Barbosa et al., 2022; Carvalho et al., 2022; Khashab et al., 2020; Park et al., 2020; Pikas et al., 2020; Rauschenberger & Baeza-Yates, 2021; Su et al., 2020). However, we acknowledge that case study results are not directly generalizable to other HEIs, requiring consideration of each institution's specificities.

The DSR methodology was employed to develop and validate the BI system implementation roadmap. Specifically, we adopted the Peffers et al. (2007), approach, which consists of six steps: problem identification, objective definition for the solution, design and development, demonstration, evaluation, and communication. This systematic approach enabled us to create a structured model that serves as a visual and sequential guide for the effective implementation of BI solutions in HEIs. The utility of DSR in this study lies in its ability to create an artefact (the roadmap) that is iteratively validated based on feedback from users and experts, ensuring its relevance and practical effectiveness (Apiola & Sutinen, 2021; Barbosa et al., 2022; Doyle et al., 2016; Fernández-Cejas et al., 2022; Su et al., 2020).

Focus groups were used to identify key performance indicators (KPIs) to be systematized in the dashboards. The ability of focus groups to create a space for participants to share perspectives and narratives collectively was particularly effective in gaining detailed insights in a short time (Gundumogula, 2020). Plummer (2017) highlights the usefulness of focus groups for exploring individuals' opinions, ideas, attitudes, and experiences on specific topics, recognizing their ability to reveal complexity and nuance. This approach was complemented by semi-structured interviews, which served as a data collection tool to validate the applicability and effectiveness of the developed roadmap and dashboards. Khan et al. (2020) recommend using interviews in design science and action research to develop and test solutions to practical problems.

Interviews are a qualitative data collection method that can be used to demonstrate the applicability and validity of an artefact in practice. When it comes to validating an artefact such as a system, process, method, or solution, interviews can play a crucial role by allowing researchers to obtain direct and in-depth information about the artefact's perception, use, and impact on real activities (Islind & Lundh Snis, 2017; Kutay & Oner, 2022; Kyza et al., 2022; Sanni-Anibire et al., 2021; Viberg et al., 2018). Interviews allow interaction with relevant actors or experts to gather information, opinions, and feedback about the artefact. The specific purposes and outcomes of interviews may vary depending on the context and objectives of the research (Fernández-Cejas et al., 2022; Kayanda et al., 2023; Yildiz et al., 2021).

It is also common to use a questionnaire as a guide during an interview to carry out the validation of an artefact or solution. The use of a structured questionnaire can help guide the interview and ensure that specific and relevant information is obtained from participants while keeping the process organized and focused on the validation objectives (Baba et al., 2021; Pfeiffer et al., 2018). Thus, using an interview questionnaire as a roadmap for conducting validation offers several advantages that can significantly contribute to the data collection process and the quality of the results obtained.

The actors interviewed were selected based on their expertise and involvement in the BI implementation process, including IT staff, management, and end-users. A purposive sampling method ensured participants had relevant experience, with the sample size determined by data saturation, ensuring comprehensive coverage of the necessary insights.

Data were collected through semi-structured interviews and focus groups, guided by a structured questionnaire. These methods were chosen for their flexibility and ability to capture detailed, context-specific information, facilitating the identification of KPIs. The focus groups allowed for the collection of diverse perspectives, while the interviews ensured consistency across sessions.

The collected data were analysed using thematic analysis, which involved coding the data to identify patterns and themes related to the implementation and validation of the BI system. This method provided a comprehensive understanding of the challenges and successes experienced during the BI implementation process, highlighting areas for improvement.

In summary, this study employed a research methodology that combines the strengths of case study research, DSR, and qualitative data collection methods to develop and validate a roadmap for BI system implementation in HEIs. The careful selection of the actors, structured data collection, and rigorous data analysis ensured the findings' reliability and

validity, offering insights for future BI implementations in similar contexts.

3 VALIDATION OF THE ROADMAP

Validating a roadmap is the process of evaluating and verifying the effectiveness, feasibility and accuracy of a roadmap. This process covers the assessment of that roadmap against the specific criteria or objectives defined, to ensure its reliability and suitability to guide decision-making and achieve the desired results (Castro et al., 2022; Jalundhwala & Londhe, 2023; Kerr & Phaal, 2022; Ozcan et al., 2022). It is important to note that the validation process can vary depending on the specific context and objectives of a roadmap (Ekenna et al., 2016; Jalundhwala & Londhe, 2023; Juaristi et al., 2020; Mitchell & Clark, 2019; Sareminia et al., 2019).

Validation of a roadmap therefore involves careful analysis and review of the proposed plan to ensure that it is realistic, achievable and in line with HEI objectives and resources. A roadmap is a strategic guide that describes the key milestones, objectives and actions required to achieve a particular goal or project. Validation of the roadmap is a critical step in ensuring that the plan is viable and that efforts are directed effectively. Validation of a roadmap is essential to avoid problems, optimise resource allocation and increase the likelihood of success in achieving the outlined objectives, ensuring that the roadmap is an effective tool for guiding the planning, execution and monitoring of strategic initiatives. On the other hand, validating a roadmap involves a systematic approach that includes careful analysis of the elements of the plan, as well as obtaining feedback and validation from stakeholders.

Expert validation of a roadmap consists of obtaining information, analysis and opinions from highly qualified and experienced professionals in areas relevant to the plan in question. These experts have technical, strategic or specific domain knowledge that can enrich the assessment and improvement of the roadmap. Expert validation thus helps to ensure that the plan is well-supported, realistic and in line with best practices and trends (Chofreh A. G. et al., 2016; Münch et al., 2019).

3.1 Validation Process

To carry out the validation of a roadmap, to verify that it meets the proposed requirements and contributes to solving the specified problem, it is important to follow a structured and focused approach. The steps required to validate the roadmap with experts, taking into account these objectives, could be as follows:

1) Expert selection: Identify and involve subject matter experts or stakeholders with relevant knowledge and experience in the area covered by the roadmap (Claessens et al., 2022; Zuo et al., 2022).
2) Expert review: Share the roadmap with the selected experts and ask for their comments, opinions and recommendations on the content, structure, feasibility and alignment of the roadmap with the intended goals (Claessens et al., 2022; Rust et al., 2016; Zuo et al., 2022).
3) Expert evaluation criteria: Define evaluation criteria or guidelines to assess the validity, effectiveness and potential for success of the roadmap. These criteria may include factors such as clarity, completeness, relevance, feasibility, and alignment with industry standards or best practices (Juaristi et al., 2020).
4) Gather feedback: Conduct interviews, surveys or workshops with experts to gather their comments, opinions and suggestions on the roadmap. This may include structured questionnaires, open discussions or specific evaluation forms (Baranowski & Damaziak, 2021; Ekenna et al., 2016).
5) Iterative refinement: Incorporating the feedback and recommendations provided by the experts into the roadmap, making the necessary adjustments, revisions or additions to improve its quality, accuracy and usability (Damasco et al., 2020; Ozcan et al., 2022).
6) Consensus building: Facilitating discussions and collaborative sessions between experts to reach consensus on the validity, feasibility and potential impact of the roadmap. This may involve resolving conflicting opinions, addressing concerns and refining the roadmap based on collective expertise (Horry et al., 2022).
7) Documentation and reporting: Document the feedback received from experts and any changes made to the roadmap based on their input. This documentation serves as evidence of the validation process and provides transparency and accountability (Horry et al., 2022; Ozcan et al., 2022).

The development of a questionnaire as a roadmap for carrying out validation, based on previous studies and in particular the recommendations of Apandi and Arshah (2016), involves the creation of structured and relevant questions that address the main aspects of

validation. The steps required to develop a questionnaire based on these references could be as follows:

1) Define the validation objectives: Before creating the questionnaire, clearly define the validation objectives. For example, if the authors highlight the importance of usability and perceived benefits, it is important to define your objectives for assessing these aspects;
2) Identify key topics: Based on the references and validation objectives, identify the key topics you want to address in the questionnaire. For example, you could include topics such as usability, effectiveness, efficiency, benefits and suggestions for improvement;
3) Create structured questions: develop specific questions for each of the identified themes. Check that the questions are clear and address relevant aspects of the validation;
4) Organise an interview script: Organise the questions in a logical sequence to create an interview script. Start with introductory questions, such as information about the participant's profile, and follow with questions about the key issues;
5) Introduce the questionnaire in the interview: During the interview, explain the purpose of the questionnaire and how it will be used as a guide to conduct the artefact validation discussion;
6) Conduct the interview: Follow the interview script by asking the questions in the questionnaire and allowing the participants to respond. Use the answers as a basis for further discussion;
7) Adapt and explore information: Be open to exploring additional information that may arise during the interview, beyond the questions in the questionnaire. This can enrich the validation;
8) Record responses: Record participants' responses accurately and in detail, noting both direct responses and additional information shared;
9) Analyse the data: After the interviews, analyse the responses to the questionnaire and the additional information gathered. Look for patterns and trends;
10) Describe the results: Use the questionnaire responses and information gathered to describe the results of the validation, comparing them with the recommendations of the references and highlighting points of agreement and disagreement.

3.2 Validation of Dashboards with User Groups

The implemented roadmap presented a set of decision support dashboards based on the processes, decision points and stakeholders identified in the HEI. The dashboards provide advanced functionality that allows users to access automated results and instant visualisations that meet the identified information needs. These tools can present real-time updates, analyses of historical trends and graphical representations of KPIs, improving the ease of interpretation and analysis (Calitz et al., 2018; Scholtz et al., 2018).

The KPIs to be systematised in the dashboards were identified through a focus group involving various stakeholders, including representatives of the rector's office and various UTAD departments and services. Table 1 shows these KPIs, numbered according to their relevance and the regularity with which they are consulted, and categorised according to the following areas of UTAD activity: a) Research Projects (RP); b) Technology Transfer (TT); c) Teaching and Quality (TQ); and d) Pedagogical Innovation (PI), with the matrix variable (MV) denoted by "MV".

Table 1: KPIs identified at the UTAD.

MV	KPI
RP 1	Number of researchers
RP 2	Number of scientific outputs in the Scopus database
RP 3	Financial - Revenue obtained
RP 4	Number of funded projects
RP 5	Number of research units
RP 6	Number of grant holders
RP 7	Funding received for projects by total revenue
TT 1	Number of patents
TT 2	Number of spinoffs
TT 3	Provision of services - Financial Revenue
TT 4	Number of partnerships and projects to promote innovation
TT 5	The number of entrepreneurs supported
TQ 1	Number of students
TQ 2	Number of programmes with accreditation capacity
TQ 3	Percentage of graduates
TQ 4	School success - Pass rate
TQ 5	Number of master's and doctoral theses completed (2nd and 3rd cycle only)
TQ 6	Number of degree programmes

Table 1: KPIs identified at the UTAD (cont.).

MV	KPI
TQ 7	Number of mobility programmes
TQ 8	Employability rate
TQ 9	Dropout rate - Re-enrolment rate
TQ 10	Number of subjects
TQ 11	Student satisfaction with teaching staff
TQ 12	Number of candidates
TQ 13	Number of professors
PI 1	Programme price/student ratio by number of students
PI 2	Number of non-degree programmes

Table 2 and Table 3 show the KPIs that make up the main dashboard, taking into account the characteristics of its size.

Table 2 describes the KPIs with annual/semi-annual operation, with the MV identified by "MVA".

Table 2: List of KPIs that make up the UTAD main dashboard - Annual/semi-annual operation.

MV	KPI	Relevance
MVA 1	TQ 1	Total number Number per cycle Percentage of international students per cycle
MVA 2	TQ 3	Total percentage Percentage of women
MVA 3	TQ 5	Total number Number per cycle (2nd and 3rd cycles only)
MVA 4	TQ 8	Total percentage
MVA 5	TQ 9	Total percentage of students who drop out
MVA 6	PI 2	Total number Number by typology - Postgraduate and other non-degree programmes Total number of students in non-degree programmes
MVA 7	RP 1	Total number Percentage of women
MVA 8	RP 4	Total number Total amount financed for projects
MVA 9	RP 7	Total percentage
MVA 10	TT 3	Invoiced value of services rendered Contracted value of services rendered

Table 3 describes the KPIs with the monthly operation, with the MV identified by "MVM".

Table 3: List of KPIs that make up the UTAD main dashboard - Monthly operation.

MV	KPI	Relevance
MVM 1	RP 2	Total number Number by typology Number by quartile
MVM 2	RP 3	Total value of research income
MVM 3	RP 6	Total number Percentage of women Percentage of internationals Number by type of grant holder (research initiation grant holders, research grant holders and post-doctoral grant holders)
MVM 4	RP 7	Total percentage
MVM 5	TT 1	Total number Number by state (submitted, granted and active) Number per national or international
MVM 6	TT 3	Invoiced value of services rendered Contracted value of services rendered
MVM 7	TT 5	Total number Total number of companies Total number of jobs in incubators Total number of projects supported

In terms of relevance, the following classifications have been taken into account:

- Highly relevant: Key indicators that have a direct impact on strategic decisions and reflect the overall performance of the IES;
- Relevant: Indicators that are fundamental to the management of some specific areas and can influence decisions on a more frequent basis;
- Substantially relevant: Indicators that provide useful information but are not critical for decision-making;
- Not very relevant: Indicators that provide secondary information, i.e. that rarely influence major decisions or strategies.

Concerning the periodicity of monitoring, the following classifications have been taken into account:

- Monthly: Indicators that require frequent review and analysis due to their direct impact on operations or short-term decisions;

- Half-yearly: Indicators that can be monitored in the medium term, often in line with academic cycles;
- Annual: Indicators that show long-term trends and performance and are generally aligned with the financial calendar or academic year.

Validating dashboards with user groups is a critical step in ensuring that the BI solution meets the needs of its users and provides relevant, actionable information. By involving users in the validation process, HEIs can ensure that dashboards meet the specific needs of their users, improve usability, and enable decision-making based on accurate and relevant information (Laurent et al., 2021; McCoy & Rosenbaum, 2019; Roberts et al., 2017; Schall et al., 2017; Weggelaar-Jansen et al., 2018).

Validation ensures that a dashboard is designed with the end user in mind. By involving users directly in the validation process, the tools developed are more likely to be intuitive and effective for their purposes. Even with careful design, usability issues can arise that only become apparent when a dashboard is tested in real-life situations. Validation helps to identify and correct these problems. Validation can reveal whether the metrics and data presented are important and useful to a target audience.

A well-validated dashboard allows users to quickly get the information they need to make effective and informed decisions. In addition, tweaking a dashboard after launch can be costly in terms of time and resources. Early validation can avoid unnecessary work and ensure that the final product meets users' needs. If a dashboard meets users' needs and is easy to use, it is more likely to be widely adopted and used regularly.

Users can provide valuable information about additional features or customisations that can further enhance a dashboard. User validation helps build trust in the system. When users see that their opinions are valued and taken into account, they are more likely to trust and adopt the tool. Validation can also reveal gaps in users' digital literacy, indicating the need for additional training or support. By involving multiple user groups in validation, HEIs can ensure consistency in the presentation and interpretation of data, so that all users understand the metrics in the same way.

In short, validating dashboards with user groups is a critical step in ensuring that data visualisation tools are not only technically correct but also truly useful and relevant to those who rely on them to make informed decisions.

In turn, identifying the user groups in each context is a critical step in ensuring that dashboards are well-constructed and truly useful for decision-making. Each group uses information differently, depending on their responsibilities and objectives. Validating dashboards with specific groups can highlight the need to personalise the presentation of information, making it more relevant and easier to understand for each group. By interacting with specific user groups, it's possible to determine which data is most relevant, ensuring that a dashboard displays information that's important to that group's decision-making. Feedback from different groups can also provide information about the usability of the dashboard in specific contexts, leading to improvements in design and navigation. When a dashboard is designed with the contextual needs of a group in mind, that group is more likely to adopt the tool and use it regularly.

Taking into account the case study of a HEI, the approach chosen for the validation of this work consisted of a series of semi-structured interviews divided into three sections: i) Presentation of the research and demonstration of the dashboards; ii) Testing of the dashboards by the experts; iii) Answers from the experts. These three phases made it possible to obtain information on their applicability and effectiveness. A more detailed explanation of each phase is given below.

Phase 1 was structured to ensure a thorough understanding and effective engagement of the experts involved. This process began with a detailed introduction to the research, which clarified the overall objective of the study and contextualised the importance of BI dashboards in the HE environment and their potential impact on decision-making. The specific objectives of the validation were then defined, providing a clear understanding of the goals to be achieved.

The dashboards that had been developed were then presented, providing an overview of the BI tools that had been created, the types of information they presented and how the data was visualised. This stage included a detailed explanation of the main elements of the dashboards, such as graphs, tables and interactive filters, highlighting their relevant features.

This was followed by a hands-on demonstration of the dashboards, navigating through the different functionalities in real-time and demonstrating how users can interact with the components and explore the data available. This demonstration illustrated the user's ability to filter information, access specific details and understand the trends and insights provided by the dashboards.

Finally, the key functionalities implemented in the dashboards to enrich the user experience and support informed decision-making were addressed. During this process, the experts were allowed to clarify any doubts and provide answers to the questions raised, ensuring a full understanding of the research and the dashboards developed.

In phase 2, the experts had the opportunity to interact directly with the dashboards developed, mimicking the experience of real end users. This phase started by giving the experts access to the dashboards in a realistic environment, allowing them to explore them independently. This encouraged active interaction with the dashboards by applying filters, selecting different parameters and experimenting with interactive features such as drilling down into graphs or tables.

During this testing phase, the experts were encouraged to record their observations and identify any problems or opportunities for improvement. This included aspects relating to usability, clarity of information presented, ease of navigation and system response time. Feedback was requested in real-time, with opinions and experiences shared as participants explored the dashboards, to capture the most immediate and authentic impressions.

The experts were given sufficient time to explore the dashboards extensively, ensuring that they had the opportunity to properly evaluate the tools. After this period of independent exploration, the test was completed and the next stage of validation was carried out, which involved answering a series of structured questions. This approach made it possible to assess not only the usability and effectiveness of the dashboards but also the relevance of the information presented, providing valuable feedback to improve the BI solutions being developed.

The third and final phase of validation centred on collecting the experts' answers to a set of predefined questions. This stage began with a presentation of the questionnaire to the experts, clarifying the purpose of the questions and the importance of the answers for validating the study. It was ensured that the experts understood the value of their contributions to the research.

The questionnaire consisted of a series of structured questions designed to assess various aspects of dashboards, including usability, effectiveness, perceived benefits, challenges faced and possible improvements. Experts were encouraged to provide detailed answers, motivating them to freely share their opinions and experiences related to the use of dashboards.

During the response process, additional discussions took place, allowing certain issues to be explored in more depth and new information to emerge from the conversations. All responses were carefully recorded, both through written notes and audio recordings, to ensure the accuracy and integrity of the data collected.

Where necessary, the experts' doubts about the questions posed were clarified to ensure full understanding and informed responses. At the end of the question and answer session, the experts were thanked for their valuable participation and asked for any final comments or additional observations, thus concluding the final phase of the Dashboard validation interview. This stage was essential in gaining in-depth insight into the users' experience of the dashboards and was instrumental in validating and improving the proposed BI solution.

3.3 Changes Made

Following the interviews carried out during the validation process, it was necessary to make several changes to the presentation of the dashboards, although these were not very significant. It was also necessary to make some changes to the definition of the KPIs, both in terms of the calculation algorithm and their presentation. These changes were important to improve the effectiveness and efficiency of the dashboards in question.

Figure 1 shows an example of the HEI BI system after these corrections:

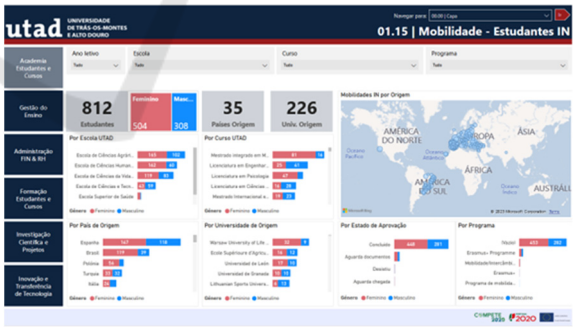

Figure 1: UTAD BI system.

3.4 Applicability and Reproducibility

One of the key issues raised during the review was the applicability and replicability of the proposed roadmap in different HEIs contexts, taking into account the diversity of processes between HEIs on different continents and between public and private institutions with different profiles.

The roadmap presented in this study has been designed to be flexible and adaptable to a wide range of educational contexts. During the validation process, it was observed that, despite the specific differences of each institution, there are common elements that allow the roadmap to be adapted to different realities.

In particular, the selection of KPIs has been made to include metrics that are broadly relevant to management and strategic performance in different HEIs. However, we recognise that the diversity of administrative and pedagogical processes between HEIs on different continents, and between public and private institutions, may require specific adjustments to the proposed roadmap.

To address this diversity, the study suggests that dashboards and KPIs should be tailored to the specific needs and characteristics of each institution. This includes taking into account cultural, regulatory and operational factors that may influence the implementation and use of BI systems in different HEIs contexts.

In addition, the validation methodology used, including direct interaction with end users and experts, proved effective in identifying and resolving usability issues and adapting dashboard functionality to meet the specific needs of users. This iterative process of validation and adaptation is key to ensuring that the BI system is truly useful and applicable in a variety of scenarios.

Thus, although the roadmap has been validated in a specific case study, we believe that its structure and approach can be adapted to other types of students and HEIs contexts, with appropriate modifications to reflect the particularities of each institution.

4 CONCLUSIONS AND FUTURE WORK

This study provides a analysis of how an HEI can effectively validate the implementation of a BI system, serving as a practical guide for institutions aiming to enhance strategic management and performance monitoring through data analysis. The methodology involved reviewing the current state of knowledge, consulting a panel of carefully selected experts, and crucially, applying a case study at the UTAD. This process validated the relevance and effectiveness of the proposed roadmap and demonstrated its practicality in HEIs, illustrating how theoretical strategies can be translated into practical applications within the higher education context.

The implementation of this roadmap in a specific HEI proved to be a fundamental step in the effective implementation of BI systems, emphasising the need for the active and ongoing involvement of all stakeholders. This interaction ensures that the roadmap remains relevant and up to date with the evolving challenges of higher education. The case study provided important insights into the practical implementation of BI systems, highlighting the crucial role of the roadmap as a facilitator of evidence-based decision-making and the need for regular updates to respond to new trends and challenges.

A key aspect of this research was validating dashboards with user groups to ensure these tools met the specific needs of end users, enhanced usability, and effectively supported informed decision-making processes. Direct interaction with users underscored the importance of post-implementation adjustments and the need for additional support or training, reinforcing the iterative and adaptive nature necessary when implementing BI solutions in higher education.

This study emphasises the importance of careful selection of experts and detailed analysis of the feedback gathered to ensure that the roadmap not only meets the immediate needs of the HEIs but also has the flexibility to adapt to future requirements. The use of semi-structured interviews proved to be a valuable resource for gaining in-depth insight into the functionality and effectiveness of the proposed BI system, allowing fine-tuning to better align the system with user needs.

In summary, this study lays the foundations for future research and practice in the area of BI in higher education and presents a guide to the validation and implementation of BI systems in higher education. By highlighting the key steps for effective validation and the importance of continuous stakeholder engagement and roadmap updating, this research provides an adaptable model that can be applied in a variety of educational contexts to optimise strategic decision-making and organisational performance.

For future research, we suggest analysing the roadmap's applicability in a wider range of educational contexts, covering HEIs with different characteristics, sizes and capacities. This methodological expansion could significantly enrich the understanding of the roadmap's adaptability to different institutional realities. In addition, conducting comparative studies between various HEIs that have implemented the roadmap would provide detailed insight into effective practices and common challenges, fostering a richer understanding

of the dynamics that influence the successful implementation of BI systems in HEIs.

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