Faster and Smarter Budgeting in Higher Education: A Data-driven Approach to Strategic Financial Planning based on Design Science Research Methodology

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Abstract

In Higher Education Institutions (HEI), the dynamics of knowledge and the need for innovation co-exist with of sustainability and efficiency challenges. Information is difficult to consolidate and interpret because the environment is growing increasingly complex and fragmented. As data is scattered across multiple systems, the processes of collecting, cleaning and integrating are time-consuming and require significant resources. This makes it difficult to aggregate information for more effective decision-making. Therefore, the use of Business Intelligence (BI) is essential for facing growing competitive and operational pressures. This paper presents the development of ERPBI Budget Control Map, which is intended to support decision-making in the administrative HEI departments. Based on Design Science Research Methodology, the artefact was developed to centralise financial, human resources and academic data, optimizing the budgeting process and facilitating the identification of deviations and cost-saving opportunities. The findings demonstrate increased operational efficiency and reduced costs, as well as the importance of fostering a data-driven culture and adopting an integrated strategy in HEI. Beyond these technical outcomes, this project revealed that true innovation in BI in HEI goes beyond processes and tools: real transformation requires a deep understanding of organizational dynamics and the surrounding context, combining digitalization with strategic insights.

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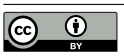

ICCSIT 2025, Paris, France

ACM ISBN 979-8-4007-1858-8/2025/10
https://doi.org/10.1145/3783862.3783906

CCS Concepts

• **Data management systems**; • **Information systems applications**; • **Visualization systems and tools**;

Keywords

Business Intelligence, Design Science Research, Higher Education Institutions, Data-driven decisions, Decision Support Systems, Financial Planning

ACM Reference Format:
Tiago Faustino-Mendes, Isabel Pedrosa, Miguel Ribeiro-Campos, and Rafael Lopes. 2025. Faster and Smarter Budgeting in Higher Education: A Data-driven Approach to Strategic Financial Planning based on Design Science Research Methodology. In *The 18th International Conference on Computer Science and Information Technology (ICCSIT 2025), October 27–29, 2025, Paris, France*. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3783862.3783906

1 INTRODUCTION

Digital transformation has been redefining how organizations operate in the global context, driving a paradigm shift in information management and strategic decision-making, as data emerges as the most valuable asset, by translating large volumes of data into concrete insights to support informed decisions, optimize operations, and strengthen competitiveness. This reality is particularly acute in Higher Education Institutions (HEI), where knowledge dynamics and innovation needs co-exist with complex challenges of sustainability and operational efficiency.

The contemporary context necessitates data-driven decisions across all sectors, enabling organizations to anticipate trends, allocate resources efficiently, and proactively mitigate risks. For HEI, this imperative is even more pressing, especially concerning budget control. These institutions face multifaceted pressures: academic accreditation requirements, internationalization processes, and operational efficiency demands intersect with chronic data

fragmentation across financial, human resources, and academic systems. As [1] observed, this heterogeneous environment breeds error-prone manual processes—often spreadsheet-dependent—that delay budget consolidation and limit responsiveness to expenditure deviations or resource reallocation needs. Without integrated analytical tools, HEI struggle to align spending with strategic objectives, undermining both financial sustainability and institutional agility.

Addressing this critical gap, our research bridges theoretical Business Intelligence (BI) frameworks with practical implementation in HEI. We present a practically applicable framework for BI deployment in budget control, materialized through the ERPBI Budget Control Map artefact. Our specific objectives are to demonstrate how the Design Science Research (DSR) methodology enables context-sensitive BI development in complex HEI environments; validate the artefact's impact on operational efficiency, cost reduction, and data-driven culture; identify organizational dynamics beyond technical tools that determine sustainable BI adoption; and provide a replicable model for integrating financial, HR, and academic data to support proactive decision-making.

This paper is organized as follows: on introduction, the context, objectives and methodology are presented. Section 2 corresponds to Business Intelligence in Higher Educations Institutions. Section 3 presents the Design Science Research Methodology and how was the artefact developed by following DSR. On Section 4 the artefact is presented. Finally, the conclusion summarizes how the objectives were achieved, discusses the contributions, limitations and future work.

2 BI IN HIGHER EDUCATION INSTITUTIONS

In recent years, HEI have increasingly adopted the use of data to support evidence-based decision-making. As a result, there is now a greater focus on using data and analytics to guide decisions and improve operations. The implementation of BI systems in HEI has proven to be an innovative approach to addressing contemporary challenges in the sector, such as competitiveness, operational efficiency, and the need for quick and informed decisions. Universities have recognized that, in order to remain competitive, they need systems that help them make informed and agile decisions. Several HEI have already adopted these technologies, while others are in the process of implementation. BI in HEI not only improves the quality and value of decision-making processes, but also allows centralized access to critical data, such as student, employee, faculty and financial data. This data can be used by different departments to support strategic and operational decisions [2].

Currently, HEI adopt a wide variety of approaches to implementing business intelligence (BI). However, regardless of the chosen method, the goal remains the same: to extract data from business systems and transform it into useful information for decision-making purposes [3]. HEI differ from other sectors, including other education subsystems, in that they have specific management strategies and missions. There is a clear need to improve decision-making processes at all levels and in all areas of these institutions. Enterprise architecture is recognized as an essential tool for aligning organizational strategic objectives with technological capabilities. However, its practical application is not yet widespread in HEI [4].

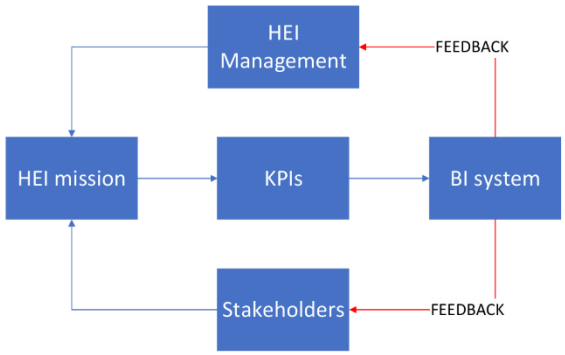

Figure 1: HEI, Data Quality Assurance and BI. Source: Sorour et al. (2020:4)

Key Performance Indicators (KPI) are fundamental to evaluating these institutions' performance in specific areas, such as teaching, learning, and research. These indicators enable actual performance to be measured and compared with established goals, helping to determine whether the institution is aligned with its mission and strategic objectives. However, teachers often view the collection and analysis of data for course accreditation and quality assurance at HEI as bureaucratic and time-consuming. Several studies address the architecture of HEI business intelligence (BI) systems, which generally include three main layers: (1) the data source layer; (2) the data extraction, transformation and loading (ETL) layer; and (3) the data presentation layer, which includes dashboards for monitoring teaching and learning processes [5].

Figure 1 illustrates a model for BI systems in HEI, highlighting the dynamic cycle between administration, stakeholders and strategic objectives.

The use of dashboards in business intelligence (BI) systems in higher education institutions (HEI) remains largely unexplored, and it is essential to understand how they are adopted, given their potential as a strategic resource for decision-making. Simultaneously analysing current and historical data is also crucial for identifying changes and trends, as well as possible adjustments to the indicators used. Thus, the data presentation and monitoring layer can consist of dashboards and balanced scorecards to enable better management of HEI performance indicators. These tools provide decision-makers with timely strategic information and allow them to identify trends, patterns, and anomalies [4]. BI adoption can cover different HEI departments, contributing to more informed decision-making and supporting the institution's strategic objectives. Effective implementation of a BI system requires the development of a structured plan including specific architecture and guidelines. Figure 2 illustrates an example of a BI model for HEI.

Implementing BI in HEI presents several challenges, including [1]: 1) Data integration: The large volume of data generated daily by various applications and devices, coupled with the heterogeneity of IT systems, complicates the process of integrating and analysing data [7]; 2) Access to information: The hierarchical structure of HEI and the levels of power in academic departments may limit access to information; 3) Institutional pressures: to increase student

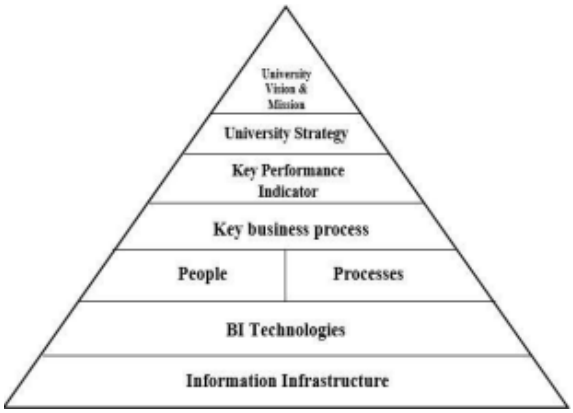

Figure 2: BI for HEI. Source: Miskon et al. (2016:3)

admissions, internationalization, and innovation creates a highly complex environment for HEI.

An important strategy for continuous improvement in HEI is the implementation of knowledge management (KM). KM can become a differentiating factor, enabling the provision of excellent educational services. Furthermore, KM can enhance the efficiency of administrative and academic processes [1].

In the United Kingdom, HEI reported significant challenges in developing and implementing BI, including misaligned expectations among stakeholders, such as senior management, BI providers, faculty, and administrators. The lack of a GC structure and ongoing communication between stakeholders can lead to conflicts of interest and priorities. In addition, issues such as data accessibility, ownership, quality, and timeliness are critical challenges, as are data cleansing and reformatting [8]. HEI need quick and accurate insights to predict risks and opportunities. However, the large amount of data from multiple, often contradictory sources makes this process challenging. The effective use of data from different sources is crucial to support the vision and mission of each institution [9].

According to [10], the benefits associated with BI in HEI, namely improved decision-making and resource allocation, are a significant incentive for its implementation. On the other hand, competitive pressure does not appear to have a significant influence on this process, suggesting that the motivation for HEI to adopt BI stems mainly from institutional factors and perceived benefits, rather than competitive pressure.

Although some studies on business intelligence (BI) in higher education institutions (HEI) exist, it can be observed that research has followed two distinct paths: one theoretical and the other practical. Most studies focus on describing the benefits of using BI, while research dedicated to its practical implementation is still scarce [4].

But there's one thing that these studies all have in common: for BI to be useful for an organization, it must be driven from the top. Senior management should have a vision for BI, provide the necessary resources, and insist on the use of information-based decision making [11].

With this involvement, the BI solution will most likely be aligned with the organization's objectives and its necessities. The development of these tools in HEI is largely based on fundamental research in predictive analysis and data mining. While the recent integration of AI and machine learning approaches is a positive step forward, it is important to acknowledge that this shift may overlook the importance of qualitative and contextual factors in education. Therefore, it is essential to critically analyse the impact of these technologies on different institutions, particularly those with limited technological capabilities, paying special attention to the long-term effects. From a practical point of view, BI's potential to improve decision-making processes is evident, although its implementation varies significantly between HEI, particularly in countries with limited resources. Presenting practical case studies that demonstrate the effective application of BI is essential to enable the generalization of results to a wider range of institutions [12].

Table 1 summarizes key contributions from selected literature. The studies reviewed highlight both the promise and challenges of BI implementation – from technical issues, such as data integration and dashboard design to institutional factors like leadership alignment and stakeholder engagement.

In summary, implementing BI in HEI offers significant opportunities to improve decision-making and operational efficiency. While integration challenges, access to data and information, and knowledge management pose significant obstacles, a structured approach and aligned stakeholder expectations can transform HEI into data-driven organizations through the adoption of BI technologies.

3 METHODOLOGY

The development of BI solutions in HEI often benefits from structured, iterative methodologies that balance innovation with practical application. One such methodology is Design Science Research (DSR), which guides the creation and evaluation of artefacts that address real-world problems in organizational contexts.

DSR unfolds across several key phases, as systematized in Figure 3. The process begins with the identification of a problem and the motivation for solving it—typically rooted in inefficiencies or limitations within current systems. Once the problem is defined, the objectives of the solution are established, guiding the design and development of a prototype that integrates both technical and organizational considerations. The artefact is then demonstrated in context and evaluated for its effectiveness, often leading to further iterations based on feedback and performance analysis. Finally, the results are communicated, not only to validate the artefact but to contribute to broader institutional knowledge and practice.

In the context of implementing a BI artefact for budgeting and financial analysis, this methodology offers a robust structure for navigating complexity, ensuring relevance, and promoting continuous improvement. The following section outlines how this approach was applied in practice.

4 ERP BI BUDGET CONTROL MAP PROPOSAL

Implementing a BI solution for budget control in HEI is a complex, iterative process that combines technology, institutional context and organizational collaboration. This section describes the practical steps followed to design, build and continuously improve the HEI

Table 1: Summary of related work

Source	Main Contribution	Relation to the Objectives of this Work
Moscoso-Zea et al., (2019)	Diagnoses fragmented data and spreadsheet-based manual budgeting processes in HEI	Supports the problem identification and need for automation and data integration
Farrugia, (2023)	Outlines the strengths and limitations of BI systems in HEI, emphasizing usability	Reinforces the focus on practical, user-centered, iterative implementation
Correa-Peralta et al., (2025)	Advocates for applied studies to demonstrate and validate BI frameworks in HEI	Justifies the development of a replicable, real-world artefact in this study
Miskon et al., (2016)	Proposes a three-layer BI architecture including dashboard interfaces	Inspires the design of the Budget Control Map's technical structure
Sorour et al., (2020)	Highlights key BI components: data source layer, ETL, and dashboards	Aligns with the artefact's modular and layered implementation strategy
Vicente & Zea, (2019)	Discuss data integration challenges and the need for strong data governance	Supports the emphasis on data cleaning and harmonization during implementation
Ong, (2016)	Identifies misalignment between BI expectations and actual institutional use	Stresses the importance of stakeholder collaboration and clear communication
Hmoud et al., (2023)	Finds BI adoption in HEI driven more by institutional value than competitive pressure	Confirms the focus on internal efficiency and sustainability as key motivations
Watson & Wixom, (2007)	Emphasize leadership's role in BI vision, adoption, and strategic alignment	Justifies the involvement of Finance, HR, and top management in artefact design
Sequeira et al., (2024)	Shows that HEI often lack practical application of enterprise architecture	Validates the use of DSR to bridge theory and practice in BI development.
Drake & Walz, (2018)	BI is presented as a driver for strategic and operational decision-making.	Mirrors the artefacts' dual role in long-term planning and operational efficiency
A. Youcef, (2015)	Describes a university-wide BI strategy and sustainment model	Provides a benchmark for institutional roadmap, adoption and maturity

Budget Control Map, a decision-support tool designed to improve budgeting processes and financial analysis in HEI, highlighting a data-driven approach rooted in DSR Methodology. In this specific implementation, the main users of the tool were the Head of the Finance Directorate, the Head of Human Resources (HR) and the Institution's Chief Financial Officer (CFO), whose needs and feedback played a crucial role in shaping the artefact.

4.1 Identification and Motivation of the problem

In many HEI, the budgeting process is often hindered by fragmented systems, decentralized data, and time-consuming manual workflows. Budgeting typically involves gathering financial, HR, and academic data from various departments — often using spreadsheets or unconnected / interoperable tools — which can lead to errors, version control issues, and delays in analysis.

The absence of integration and automation reduces visibility into institutional performance, making it difficult for decision-makers to respond quickly to changes or making data-informed strategic choices. In such environments, preparing an annual budget can require extensive coordination, repeated manual data processing, and complex comparisons with historical data to identify trends or deviations.

This context underscores the need for a more integrated, agile, and reliable approach to budget control and planning. Institutions are increasingly seeking solutions that consolidate data from multiple sources, automate routine tasks, and present insights through intuitive and interactive dashboards. These tools not only save time but also increase transparency and provide a stronger foundation for evidence-based decision-making.

Typical goals for implementing such a BI solution in the context of budgeting include: 1) Data integration: Consolidate data from enterprise systems and HR platforms into a unified model; 2) Automation: Reduce reliance on manual data extraction and transformation; 3) Visualization: Enable fast, intuitive access to key metrics and performance indicators; 4) Decision support: Provide a solid analytical base to guide financial strategy and institutional planning.

While many BI initiatives in HEI initially focus on strategic oversight, they often evolve to support operational decision-making as well, extending their utility across departments and enhancing the institution's ability to act proactively.

In the case discussed in this paper, the key challenge was the inefficient and fragmented nature of financial data handling and reporting. Based on the problem analysis, the objective was defined: to develop an artefact that automates data integration from multiple sources and presents it through interactive dashboards to support timely and accurate decision-making.

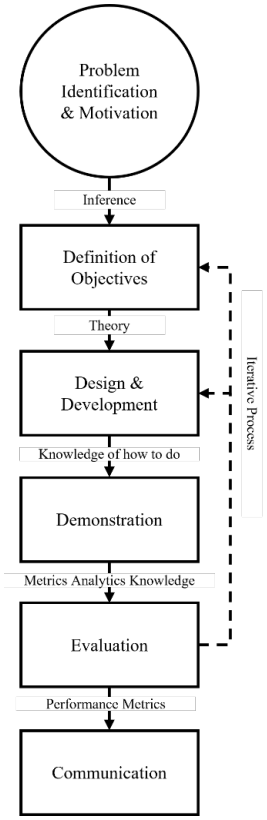

Figure 3: DSR steps. Source: Adapted from [14]

4.2 Defining Objectives and Designing & Developing the Solution

A scale of effort undertaken at the stage of designing and implementing BI varies. Such effort predominantly depends on the system complexity. However, in the majority of cases, developing a customized BI application requires a lot of time. This time is spent not only on designing individual interfaces but also on ensuring the overall logical consistency of the application [15].

Such systems are meant to provide adequate and reliable up-to-date information on different aspects of enterprise activities, making sure the system is aligned with the users' needs. After understanding the problem and its institutional context, the next step is to define what the BI system should achieve. In the context of budgeting, this often means establishing the ability to centralize and interrelate financial, HR, and academic data to support more timely and accurate decision-making. The definition of clear objectives is closely tied to understanding stakeholder needs—what kinds of questions they want answered, what information they rely on, and what gaps currently exist.

Designing the solution involves making early decisions about the technical architecture, ensuring it is flexible enough to integrate with existing institutional systems. In parallel, stakeholders—typically from finance, HR, and academic departments—should be involved in identifying relevant KPIs, key reporting needs, and usability expectations. This early alignment is critical in ensuring the BI artefact is not just technically sound but also practically relevant.

Because institutional environments vary greatly, the architecture must be flexible. For example, one institution might have a centralized ERP, while another relies on siloed systems across faculties or institutes. The BI artefact must accommodate these realities.

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4.2.1 Data Integration. Data integration is frequently one of the most demanding and critical steps in BI implementation. In HEI, financial, HR, and student data may come from disparate systems with different update cycles and varying levels of quality. Data cleaning and harmonization were necessary to ensure accuracy and consistency. Special attention must be devoted to aligning data definitions across departments to avoid misinterpretation and ensure semantic coherence in reporting. Bringing this information together requires not only technical tools, such as Power Query or SQL-based ETL processes, but also a careful analysis of the meaning and usage of each data source.

Problems such as inconsistent naming conventions, duplicated entries, and differing update schedules are common. For example, the same cost Centre might be referred to differently in HR and Finance systems, requiring harmonization to avoid distorted reports. Standardizing date formats, removing null values, and ensuring each table has a unique and coherent key structure are foundational tasks. Cleaning and transforming the data at this stage prevents analytical errors and builds trust in the system's outputs. With clean and harmonized data, the next step is to create a model that supports analysis. In most BI platforms, this involves building relationships between fact tables (e.g., transactions) and dimension tables (e.g., departments, dates, accounts). The model must support institutional needs, from high-level overviews to granular drilldowns.

Certain challenges are common across institutions, such as many-to-many relationships between students and programs or staff and departments. In such cases, bridge tables are introduced to maintain accurate relationships and avoid duplication in aggregations. Calculated metrics—such as cost per student, budget deviation percentages, or staff Full Time Employees ratios—are defined through formula languages, such as DAX, a native language from Microsoft Power BI or equivalents, depending on the platform. The model should be tested iteratively, using real data and use-case scenarios, ensuring that measures behave as expected across different filters and perspectives.

4.2.2 Visualization. Following data modelling, the design of the user interface must focus on usability and clarity. Translating a well-structured data model into intuitive dashboards is essential for adoption. The interface must be designed to serve a diverse group of users: budget managers, department heads, and administrative staff, each with different levels of data literacy.

Dashboards should present relevant financial information and KPIs, allowing filtering by department, time, or budget category, and support drill-down to explore anomalies. For instance, a user

exploring a department's overspending might drill down into individual budget lines or compare figures to previous years.

4.3 Demonstration

Effective design often involves iterative feedback sessions with users to refine layouts, adjust terminology, and ensure the information presented aligns with real decision-making workflows. It is important to acknowledge that the design process follows an iterative approach, where the initial prototype is unlikely to fully meet user needs. Continuous refinement is key.

Before institutional rollout, it is critical to test the prototype in a real-world context. This includes technical validation — ensuring performance, accuracy, and security — as well as user validation. Demonstrations with key stakeholders help surface usability issues, gaps in the data model, or missing metrics. Comparing dashboard outputs with legacy reports is a valuable technique to build confidence. Additionally, testing performance under real data volumes helps identify inefficiencies, such as long load times or filter lag, that might not be apparent during development. Gathering structured feedback during this phase helps shape final refinements.

One of the defining characteristics of effective BI implementation is its iterative nature. Once in use, the system will inevitably reveal opportunities for refinement. New user needs may emerge, existing KPIs might need redefinition, and the scope of the solution often expands to include new areas of institutional interest. For example, a budgeting dashboard initially built to compare planned versus actuals may later incorporate forecasting or predictive models. Similarly, what began as a finance-led project might evolve to support HR planning or academic resource allocation. Ongoing monitoring of usage patterns and user feedback ensures the artefact continues to evolve in line with institutional priorities.

4.4 Evaluation and Communication

The final steps in the DSR cycle involve assessing the impact of the artefact and communicating the results. Evaluation combines both qualitative insights – captured via user and stakeholder feedback – and quantitative usage metrics. Data Analytics may be in use to demonstrate how frequently dashboards are accessed and by which user groups. Measuring change over time is also important. Institutions may find that processes which previously took weeks can now be completed in days, or that staff engagement with data has increased significantly. Documenting these outcomes, along with lessons learned and future development paths, is essential to validate the solution's effectiveness and to inform other BI initiatives within or beyond the institution.

To ensure a comprehensive and relevant evaluation, it is essential to identify and engage key stakeholders who interact with the budgeting process and rely on its outcomes. These stakeholders are best positioned to assess the tool's effectiveness, usability, and strategic value. In the context of this implementation, the primary users of the BI solution were the Head of the Finance Directorate and the Institution's CFO, who are responsible for financial planning and monitoring; the Faculty Directors, who need visibility into departmental budgets and performance indicators; and the Rectorate, which requires high-level insights to support institutional governance and strategic planning. These individuals represent distinct user profiles with different expectations, data needs, and decision-making responsibilities. Engaging them in evaluation activities through structured interviews, surveys, and usage analytics provides a holistic understanding of the artefact's impact. Recognizing the diversity of user roles also helps identify areas for further refinement or expansion of the tool. For instance, while finance leaders might focus on budget execution and cost deviations, faculty directors may prioritize resource allocation across academic programs. A successful BI solution must accommodate this range of perspectives to deliver meaningful value across the institution.

5 CONCLUSION

The development and implementation of the ERPBI Budget Control Map illustrate that BI in HEI is not merely about mastering technological tools—it is about understanding the core of the organization: its priorities, its information flows, and what drives its people. In this paper, BI was not treated as a standalone technical endeavor, but as a strategic tool aligned with institutional goals and deeply informed by the needs of its users.

The success of the artefact stemmed from close collaboration with key stakeholders. This alignment between people and technology was essential to ensure that the BI system addressed real problems and delivered practical value. Tools only reach their full potential when they are co-designed with those who will use them, transforming data into meaningful insights rather than just numbers on a screen.

Moreover, this initiative was born out of strategic priorities established by top management. This involvement provided direction, legitimacy, and the necessary resources to embed BI as part of a wider institutional transformation. It also reinforced a culture of data-informed decision-making, moving beyond ad-hoc reporting toward proactive financial planning and performance monitoring.

Grounded in the DSR methodology, this paper contributes both to practice and to research. It offers a roadmap for BI implementation in HEI and highlights that sustainable innovation in BI arises not only from technology, but from the strategic alignment between people and processes.

Acknowledgments

This research wok was supported by the Polytechnic University of Coimbra scientific publication fund.

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