Developing an Ontology-Driven and Governance-Integrated Method for Information Dashboard Design

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***Abstract*—Despite the increasing reliance on information dashboards across industries, dashboard design practices remain fragmented, lacking standardized methodologies, ontological formalization, and governance integration. Addressing these gaps, this study develops a method to guide dashboard design by embedding ontological modeling and Information Governance (IG) principles. Two complementary artifacts are proposed: the Information Dashboard Design Ontology (IDDO) and the Information Dashboard Design Method (IDDM) Canvas. Using Design Science Research Methodology (DSRM) and a Unified Ontological Approach (UOA), IDDO formalizes tacit dashboard design knowledge into a structured framework, while the IDDM Canvas operationalizes this ontology into a practical design tool. Validation through the Ontological Unified Modeling Language (OntoUML) Plugin and conceptual assessment based on Unified Foundational Ontology (UFO) principles confirmed internal consistency and ontological soundness. The resulting framework integrates twelve dashboard design building blocks with eight IG principles to ensure rigor and governance alignment. The application of the IDDM Canvas demonstrated its utility in facilitating structured, replicable dashboard development. While the evaluation focused primarily on conceptual validation, future studies are recommended to empirically assess the framework's practical effectiveness across various domains and real-world projects.**

Keywords*—Information dashboard; ontological modelling; information dashboard design ontology (IDDO); information dashboard design method (IDDM) canvas; information governance (IG); unified ontological approach (UOA); design science research methodology (DSRM)

I. Introduction

Information dashboards have become essential tools for organizational decision-making, enabling users to monitor, analyze, and interpret complex data in real-time [1]. Beyond their traditional role as visualization interfaces, dashboards now function as integrated components of information ecosystems, bridging disparate systems and enhancing decision support across domains. Their widespread adoption spans over industries such as healthcare [2], [3], finance [4], urban mobility management [5], and public health [6].

Despite their prevalence, dashboard development practices remain fragmented and lack a standardized methodology. Poorly designed dashboards may lead to cognitive overload, inconsistent data representation, and misinformed decisions [7], [8]. Moreover, many existing approaches neglect the integration of governance principles, which can compromise data quality, reliability, and compliance [9], [10], and hinder organizational learning and adaptation to digital transformation [11]. Without a consistent framework that incorporates governance, organizations face challenges in aligning dashboards with strategic and operational needs. Additionally, dashboard design often relies on implicit expertise held by experienced practitioners, making it difficult to replicate or scale across teams. The absence of a formalized design method limits reuse and consistency across different contexts. While ontology has shown promise in structuring complex design logic within business modeling [12] and learning systems [13], its application in dashboard design methodology remains limited.

This study aims to address three core challenges in dashboard methodology: 1) the lack of a standardized, transferable design method; 2) limited use of ontological approaches to formalize design elements; and 3) the absence of governance integration in the design process. In response, we adopt Design Science Research Methodology (DSRM) to develop the Information Dashboard Design Ontology (IDDO) and the Information Dashboard Design Method (IDDM) Canvas. IDDO provides a structured ontological framework for modeling key dashboard elements, while the IDDM Canvas offers a practical guide for applying this framework in real-world design initiatives.

Inspired by the transformation of the Business Model Ontology (BMO) into the widely adopted Business Model Canvas (BMC), this study translates IDDO into a usable design tool through the IDDM Canvas. This approach bridges conceptual rigor with design applicability, offering a method that supports governance compliance, visual consistency, and broader usability, including by non-specialist users.

The remainder of this study is organized as follows: Section II reviews the literature on dashboard design, ontological modeling, and governance integration. Section III outlines the research methodology. Section IV details the development of IDDO. Section V presents the IDDM Canvas. Section VI discusses the conclusion which includes limitations, and future research directions.

II. Literature Review

A. Challenges in Dashboard Design and the Need for Standardization

The growing body of research on information dashboards highlights their increasing role in enhancing decision-making through structured visual representation of data. Sarikaya et al.

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[1], emphasize how organizations are increasingly relying on dashboards to transform complex datasets into actionable insights. However, despite substantial academic and industry interest, there remains a lack of formalized, standardized methodologies for dashboard development, indicating the need for more structured design approaches. Recent studies echo these concerns, particularly in sentiment-oriented and real-time dashboards that highlight interactive and data-driven needs without standardized models [58], [59].

As information systems evolve, dashboard development encounters several design-related and implementation challenges. Poor design has been linked to cognitive overload [7], reduced user engagement, and diminished decision quality [8]. These problems are exacerbated by the absence of a methodological framework that can capture and structure implicit design knowledge into standardized and reusable models. Without formalization, inconsistencies in layout, interaction, and data interpretation often emerge, leading to interoperability and usability issues. The emergence of AI-powered dashboards also illustrates this gap, where intelligent systems are deployed without governance grounding, resulting in unpredictable behavior or user distrust [60].

These challenges emphasize the need for a governance-integrated framework that promotes standardization while remaining adaptable across contexts. In practice, dashboards often serve as boundary-spanning tools between business and technical domains, requiring design methods that support both consistency and flexibility [14]. While some frameworks have shown domain-specific success, they frequently lack ontological structure and governance alignment, limiting broader application.

A synthesis of twelve recent studies (2019 to 2024), selected across healthcare, public service, urban management, and other sectors, reveals wide variation in dashboard objectives, design approaches, and governance considerations. Although many offer novel visualization strategies, they remain context-specific and difficult to generalize. This highlights the need for methodologies that support the formalization and standardization of dashboard design processes. These studies were chosen to reflect cross-sector practices, and recent publications were prioritized to capture emerging design trends and evolving best practices [59], [60].

Inspired by Osterwalder's methodology in developing the BMO [12], which successfully transformed business modeling logic into structured, transferable artefacts, this study applies a similar logic to dashboard design. It synthesizes design elements across domains to inform the development of a governance-integrated, ontology-driven dashboard design framework. The review indicates that while healthcare [3], [2] and public service [6], [15] applications dominate dashboard usage, each domain applies distinct development methods. For example, dashboards in healthcare often prioritize real-time clinical monitoring [3], [2], while those in tourism or urban management emphasize geospatial interaction and user experience [16], [15]. This diversity demonstrates the adaptability of dashboards but also highlights variations in design structures and methodological rigor across sectors.

In terms of methodological approaches, the studies span a wide range from user-centered and iterative designs to data-driven and metric-based models [7], [9], [13]. Some emphasize prototyping and stakeholder feedback [6], [4], while others rely on cognitive task analysis and real-time contextual inputs [15]. Although these approaches offer valuable insights, few provide a repeatable structure that can be generalized or scaled. This points to a pressing need for unified design frameworks that can bridge ad-hoc development with structured reusability.

Design principles also vary significantly. While some dashboards focus on tracking KPIs and trends using minimal layout structures [4], [17], others employ interactive and multi-layered design systems to serve diverse user groups [6], [5]. However, many studies underplay the importance of design consistency, hierarchy, and accessibility - factors that critically affect usability and user trust [8]. This variability in design emphasis further reinforces the case for standardized design methods that balance domain specificity with universal design principles.

Table I summarizes the key studies across domains, revealing the broad diversity in dashboard development approaches. The review demonstrates sectoral adaptability but simultaneously exposes the absence of standardized structures across organizational contexts. Recent data-driven approaches, for instance, prioritize automation and real-time responsiveness but lack a governance-aware foundation, further illustrating the gap [60].

To address the limitations identified in existing literature, this study proposes a new framework – the IDDO, which responds directly to the gaps. Existing dashboard design frameworks, while offering domain-specific solutions, exhibit fundamental limitations that make them unsuitable for systematic, governance-aligned development across organizational contexts. These frameworks rely on ad-hoc approaches without formal structure, lack ontological formalization, preventing knowledge systematization, and treat governance as external considerations rather than integrated design components [7], [8], [9], [10].

The proposed IDDO framework addresses these limitations by providing: 1) a formal ontological structure enabling systematic knowledge transfer, 2) embedded governance integration ensuring compliance by design, and 3) practical operationalization through the IDDM Canvas that translates complex structures into actionable design methodologies. This approach makes IDDO particularly appropriate for organizations requiring standardized, repeatable dashboard development processes.

This reinforces the need for a formalized modeling foundation to promote consistency, facilitate transferability, and embed governance-aware design practices. Building on these insights, the following sub-sections explore two critical dimensions essential for establishing a standardized dashboard development method: 1) ontological modeling and 2) Information Governance (IG).

TABLE I. A REVIEW OF RECENT STUDIES ON INFORMATION DASHBOARD DESIGN (2019-2024) DISCUSSED IN SECTION II

Study	Application Domain	Methodology	Key Phases	Design Principles	Key Features	Key Study Outcome
Poppe et al. [3]	Neonatal Intensive Care	User-centered design	1. Interviews with clinicians 2. Dashboard prototyping 3. Clinical evaluation	• Combine detailed and summarized data • Enable real-time monitoring • Support decision-making • Ensure ease of understanding	• Real-time monitoring • Visual trends • Clinical indicators	Web-based oxygenation dashboard for monitoring preterm neonates
Pamuk & Schuman n [4]	Financial Services	Design Science Research	1. Data understanding 2. Data preprocessing 3. Model development Model evaluation	• Simplicity: Show only essential information • Customization: Allow changes to the layout • Interactive design • Transparency and security • Regulatory compliance	• AI model creation • Performance visualization • Comprehensive reporting	AI dashboard "AIDash" for credit assessment model management
Salvi et al. [6]	Public Health	User-centered design	1. User needs assessment 2. Data integration 3. Visualization design 4. Dashboard development 5. User evaluation	• User-centered design • Data privacy and security • Actionable insights • Intuitive visualizations • Timeliness	• Overdose touchpoint visualization • Interactive visualizations • Data integration	Real-time dashboard for enhancing overdose prevention efforts
Conrow et al. [5]	Mobility Data	Iterative user-centered design	1. Identify purposes/users 2. Specify data implementation 3. Create trajectory model 4. Build with user input 5. Involve users at all stages	• User-centered design • Interactive design • Visual design for effective communication • Data model development	• Indicators and maps • Interactive filters • Dynamic features	Conceptual framework for big mobility data dashboards
Bach et al. [8]	Cross-industry	Systematic analysis	1. Define data selection 2. Establish structure 3. Design pages 4. Add interactivity 5. Select color scheme	• Optimize screen space • Use color purposefully • Provide context for data • Consider different audience needs • Accessibility considerations	• Visual display patterns • Data exploration • Information presentation	Comprehensive set of 64 dashboard design patterns
Wu et al. [7]	Data Visualization	Deep-learning method	1. Define purpose/questions 2. Select data sources 3. Choose chart types 4. Design layout 5. User testing	• Foster human computer collaboration • Balance automation with user control	• Automated visualization • Analytical insights	Deep learning algorithm for analytical dashboard assistance
Pestana et al. [2]	Healthcare	Design science research	1. Research and ETL 2. Initial proposal 3. Demonstration/evaluation 4. Feedback implementation	• Gestalt visual perception principles • Proximity, similarity, enclosure • Visual hierarchy for KPIs	• KPI monitoring • Performance comparison • Trend visualization	Web-based hospital productivity management dashboard
Balletto et al. [16]	Tourism	Convergent parallel design	1. Define framework 2. Define layout 3. Analyze characteristics 4. Collect user content 5. Develop dashboard	• Highlight points of interest • Provide detailed travel information • Intuitive geographical representation	• Walkability index • Attractiveness index • Maps and charts	Dashboard for slow tourism in green infrastructures
Young & Kitchin [15]	Urban Management	Cognitive Task Analysis	1. Establish purpose 2. Identify audience 3. User research 4. Create personas 5. Content strategy	• Integration of HCI research • User-centered civic design • Multi-platform compatibility	• Multiple visualization types • Real-time displays • Interactive features	Design guidelines for building user-centered city dashboards
Elshehaly et al. [9]	Healthcare Quality	Metric Specification Structure	1. Investigate challenges 2. Healthcare interviews 3. Design metric cards 4. Create specification 5. Deploy and enhance	• Task sequence optimization • Metric definition standardization • Visual feature consistency • Adaptable dashboard structure	• Quality metrics visualization • Adaptive displays • Metric structures	QualDash for healthcare quality improvement metrics
Ahdan et al. [17]	Energy Management	IoT implementation process	1. Assemble tools 2. Build prototype 3. Develop application 4. Test and rebuild	• Flexibility in control • Efficient energy usage • User-friendly interfaces	• Real-time monitoring • Device control • Mobile accessibility	IoT-powered mobile dashboard for energy monitoring

Kokoç & Altun [13]	E-learning	Iterative design	1. Reorganize database 2. Plan visualizations 3. Design dashboard 4. Expert feedback	• Simple and comprehensible interface Learning progress visualization	• Learning behavior visualization • Predictive modeling	Prescriptive learning dashboard for performance improvement

B. Ontological Approaches in Dashboard Design

Ontological approaches have shown strong potential in formalizing complex structures within information systems, enabling standardized representation and promoting semantic interoperability. While widely applied in domains such as business modeling, particularly through frameworks like the BMO [12], their adoption in dashboard design remains limited.

As Eppler and Burkhard [14] argue, the development of structured visualization tools necessitates a solid conceptual backbone to ensure clarity, coherence, and reusability. However, none of the twelve studies reviewed in this paper explicitly apply ontological methods in dashboard development. This absence underscores a methodological gap in current practices. Nevertheless, recent implementations in fields such as mobility analytics [5] and educational dashboards [13] demonstrate more structured design practices, suggesting the untapped potential of ontological modeling to enhance consistency, scalability, and transferability across interface designs.

Formalizing design knowledge through ontological approaches offers several advantages, particularly in enabling standardization and aligning design logic with governance structures. Guizzardi's ontological foundations [36] offer methodological rigor that supports semantic precision and conceptual clarity in defining dashboard components. Similarly, recent work by [52] highlights how unified ontological frameworks can promote consistent modeling while maintaining flexibility for contextual adaptation.

By applying ontological principles, dashboard design can move beyond fragmented, ad-hoc development toward a more coherent and reusable foundation. This shift not only supports cross-domain implementation but also facilitates the embedding of governance requirements within the design structure itself, an aspect further explored in the following sub-section on IG.

C. IG and Dashboard Design Reliability

IG offers a comprehensive set of standards and practices to ensure that information assets are managed with accuracy, security, and accountability [10]. However, a review of the twelve dashboard studies conducted in this study reveals that none explicitly incorporate IG principles into their design methodologies. While some acknowledge compliance-related concerns or data accuracy issues, governance integration is often implicit or entirely absent from the design framework.

In the context of dashboard design, integrating IG principles helps organizations align their visualization tools with broader compliance and data integrity goals. As noted by Datta et al. [18], IG frameworks play a pivotal role in maintaining the trustworthiness of information flows within decision-making systems. Organizations with established governance mechanisms also exhibit stronger information standardization across units [19]. Conversely, the lack of governance integration can result in data inconsistencies, increased risk exposure, and reduced decision reliability [20], [21]. Embedding IG principles as part of dashboard methodologies could ensure that design outputs maintain regulatory compliance and reflect high information quality [22], [23].

D. Gaps in Current Approaches and the Need for a Standardized Methodology

The synthesis of dashboard design literature highlights three persistent challenges that limit progress in establishing standardized dashboard development practices. First, most reviewed methods are highly domain-specific and lack the generalizability needed for cross-organizational adoption. Second, while ontologies have proven effective in other domains for formalizing and structuring design logic, none of the twelve studies reviewed incorporate them directly into dashboard methodologies. Third, despite growing awareness of governance importance, none of the studies examined explicitly integrate IG principles into the design process, resulting in potential risks to data reliability and organizational compliance.

These gaps emphasize the need for a standardized methodology that embeds both ontological modeling and governance structures into dashboard development. Such a framework would support methodological consistency, formalized design knowledge, and governance alignment throughout the lifecycle of dashboard creation. An ontology-driven approach that integrates IG principles potentially offers a scalable solution for organizations seeking to design dashboards that are not only functionally effective but also aligned with compliance standards, promoting greater usability, accountability, and organizational learning.

III. Methodology

This study adopts Design Science Research Methodology (DSRM) to guide the development of the IDDO and the IDDM Canvas. Rooted in Simon's foundational work, The Sciences of the Artificial [24], DSR offers a structured, artifact-oriented approach to addressing complex design problems. Originally formalized within information systems research [25], the methodology has gained traction across various applied domains, including dashboard development and business modeling [26], [27].

DSRM is particularly suited for structuring the development of purposeful tools, as demonstrated by successful applications like BMC [28]. In this study, the DSRM framework is complemented by the Unified Ontological Approach (UOA) [29], which serves as the ontology development methodology. The integration of UOA facilitates the formal modeling of dashboard design components by translating fragmented design logic into structured ontological representations that can be systematically reused across development scenarios.

The use of DSRM is justified by its effectiveness in guiding the structured development of design artefacts within information systems [30], [31], [32]. Its applicability to ontology-based design is further reinforced by recent studies on conceptual modeling frameworks [33]. Together, DSRM and

UOA form a robust methodological foundation for developing the IDDO conceptual framework and the IDDM Canvas, ensuring the resulting artefacts are valid, usable, and applicable across diverse dashboard design contexts.

A. *Research Design for IDDO Development*

This study focuses on the first three stages of the DSRM proposed by Peffers et al. [25], as illustrated in Fig. 1. The demonstration and evaluation involving dashboard mock-ups are reserved for future research, while this study represents the communication stage by detailing the conceptual and design artifacts developed for dashboard methodology enhancement.

Table II summarizes the research activities and outcomes associated with each implemented DSRM stage.

B. *Framework Development and Evaluation*

The IDDO was developed using an iterative, model-driven approach. IG principles in this study context were used as a guiding theoretical foundation and serve as the Kernel Theory, consistent with the Kernel Theory Fundamentalist perspective proposed by Gregor and Jones [35]. The adoption of a Kernel Theory reinforces the theoretical grounding of IDDO while supporting its practical application as a structured modeling tool. The structured development process was executed through four modeling and evaluation stages, as outlined in Table III. The structured modeling process establishes IDDO as a robust framework that integrates governance elements into the formal structure of dashboard design. By combining ontological rigor with compliance-oriented design considerations, the resulting framework enhances consistency, reusability, and adaptability across organizational contexts.

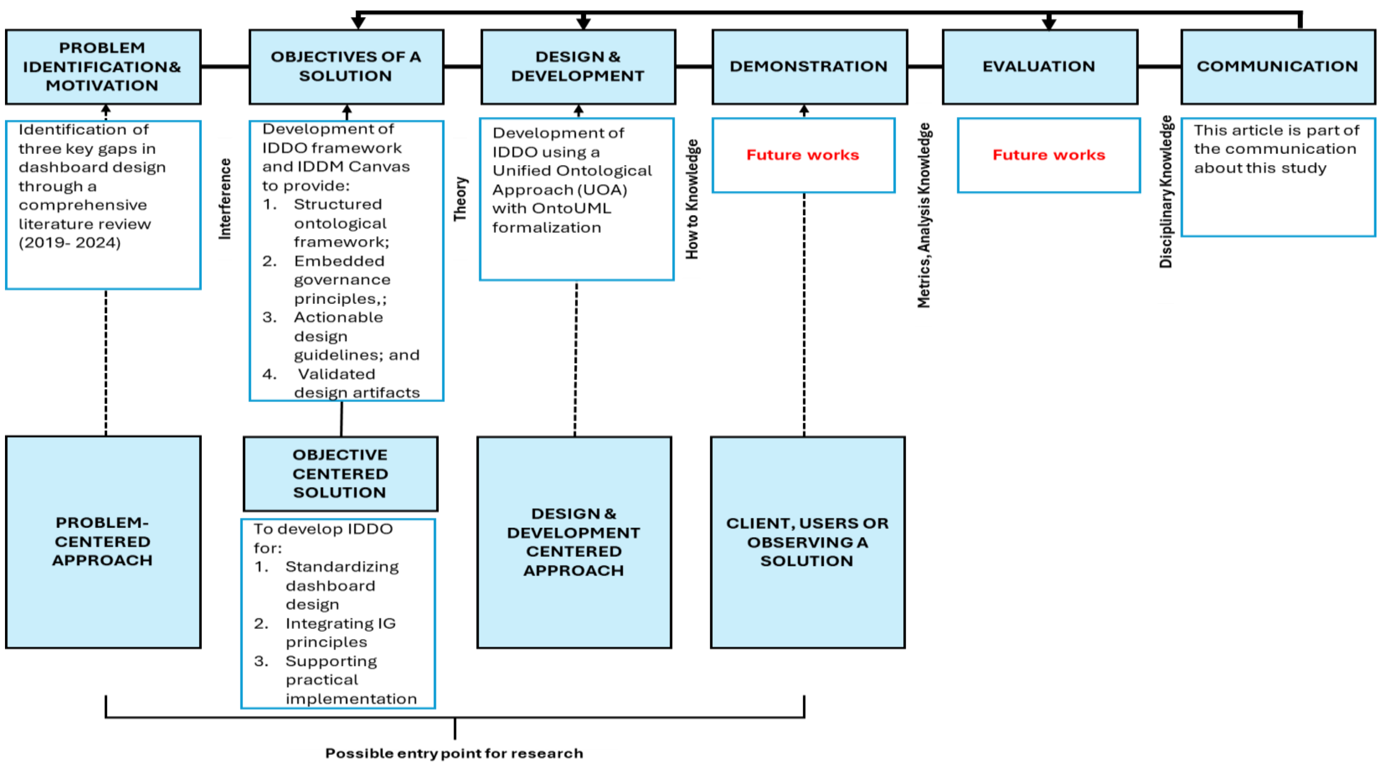

Fig. 1. DSRM implementation for IDDO development (focusing on the first three stages).

TABLE II. SUMMARY OF IMPLEMENTED DSRM STAGES

DSRM Stage	Research Activities	Outcomes
Problem Identification	Review of twelve recent studies (2019–2024)	Identified three major gaps: 1. Lack of standardized design methodology 2. Limited use of ontology 3. Absence of governance integration
Solution Objectives	Definition of design objectives and scope	Established four objectives: 1. Structured ontological framework 2. Embedded IG principles 3. Actionable design guidelines 4. Design artifact validation
Design & Development	Iterative modeling using the UOA	Developed two artifacts: 1. IDDO: an ontology-based dashboard design framework 2. IDDM Canvas: a practical dashboard design method.

TABLE III. IDDO DEVELOPMENT PROCESS

Stage	Activity	Description
UML-Based Modeling	Conceptual modeling in UML	Initial structuring of dashboard design elements using Unified Modeling Language (UML).
OntoUML-Based Refinement	Ontological formalization	Used OntoUML to enhance the semantic precision and clarity of design constructs [36].
OntoUML Plugin Validation	Syntactic model validation	Applied the OntoUML Plugin in Visual Paradigm to detect modeling inconsistencies.
Conceptual Evaluation with UFO	Ontological soundness assessment	Assessed the model against Unified Foundational Ontology (UFO) principles to verify semantic integrity.

The next section elaborates on the development of the IDDO and the formulation of the IDDM Canvas, which translates these components into a practical design methodology for dashboard development.

IV. DEVELOPMENT OF THE IDDO

The development of IDDO, the primary artifact and key contribution of this study, involves a systematic and rigorous process to establish a standardized framework for the information dashboard design method. This section details the methodical process of identifying essential building blocks, incorporating IG principles for information quality, and formalizing the ontological framework, laying the foundation for a governance-driven, standardized dashboard design methodology.

A. Establishing the Building Blocks

The building blocks of the IDDO are derived from a comprehensive analysis of recent works in dashboard design (2019-2024) as summarized in Table I earlier. Through a narrative review of twelve previous studies, key commonalities in design phases, visualization principles, and essential features were identified and summarized in Table IV.

These insights informed the derivation of twelve key building blocks within the IDDO framework. The elements were consistently observed across the reviewed studies and are conceptually organized as illustrated in Fig. 2.

This analytical process aligns with established ontology development practices, where recurring elements across multiple studies are consolidated to form structured frameworks [37], [12]. Similarly, Bernardo et al. [38] applied a systematic approach to identify critical components in the lifecycle of Business Process Management (BPM), demonstrating how synthesis of prior works can reveal design patterns suitable for standardization. Recent work by Leong et al. [57] further demonstrates the applicability of BMO-inspired approaches in developing ontologies for specialized dashboard contexts, such as virtual reality environments, reinforcing the transferability of ontological modeling principles across different visualization domains.

TABLE IV. KEY COMMONALITIES IN DESIGN PHASES, DESIGN PRINCIPLES, AND ESSENTIAL FEATURES

Commonalities		
Design Phase	***Design Principles***	***Essential Features***
• Problem identification • Design and modelling • Development and implementation • Testing and evaluation • Iterative process and feedback	• Reduce pages • Optimize screen space • Use color purposefully • User-friendly interfaces • Effective information visualization • Tailored visualization approaches • Ensure accessibility • Simplify the design	• Visual display of important knowledge • Interactive information visualization displays • Drill-down capabilities and knowledge exploration • Presentation of analytical knowledge insight

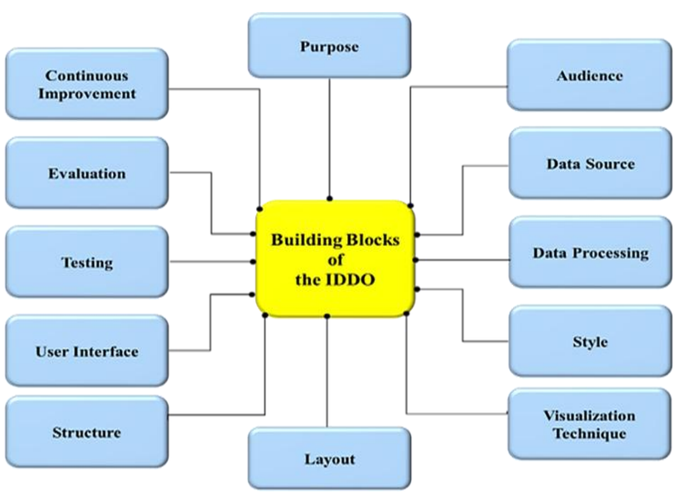

Fig. 2. Twelve key building blocks of the IDDO.

Building upon these approaches, IDDO integrates common patterns across dashboard design literature to promote semantic consistency, governance integration, and methodological standardization. The twelve building blocks illustrated in Fig. 2 were derived from these observed patterns and are summarized in Table V.

The derivation process was informed by the recurring elements identified in the reviewed studies (as shown in Table IV), but the resulting terminology was intentionally refined to ensure clarity, contextual relevance to IDDO, and ease of interpretation, while preserving the original intent of each component.

Drawing inspiration from the structure of the BMO developed by Osterwalder [12], which has been widely adopted for business model development, the IDDO building blocks are organized into three logical categories: Defining and Planning, Design and Visualization, and Testing and Improvement. This categorization reflects a structured and phased design approach, aligning closely with ontology development principles for information systems.

Table VI outlines how the twelve building blocks are distributed across these categories. The Defining and Planning category establishes the dashboard’s foundation, encompassing Purpose, Audience, Data Source, and Data Processing. The Design and Visualization category focuses on interface elements that shape user interaction, while the Testing and Improvement category supports continuous refinement through validation and quality assurance measures.

TABLE V. DERIVATION OF KEY BUILDING BLOCKS FOR THE IDDO FRAMEWORK

The Key Building Block	Commonalities From Where The Building Block Is Derived	Basis
Purpose	• Problem identification. • Deliver meaningful insights to users. • Development and implementation.	• Defines the dashboard's core problem and direction. • Guides the delivery of meaningful insights to users. • Influences all development and implementation decisions.
Audience	• Tailor best practices to the specific requirements of each domain. • User-friendly interfaces. • Tailor design approaches	• Specifies target users and their information needs. • Shapes design and functionality based on user requirements. • Enhances relevance through user-centric approaches.
Data Source	• Drill-down capabilities and data exploration. • Presentation of analytical data insight.	• Determines information range and depth for display. • Enables data exploration and drill-down capabilities. • Provides foundation for analytical insights.
Data Processing	• Reduce data selection overhead and automate selection for multiple charts. • Presentation of analytical data insight.	• Facilitates data transformation and preparation • Automates chart data selection to reduce overhead • Ensures data quality throughout the processing pipeline
Style	• Use color purposefully. • Minimize visual effects. • Create intuitive and visually appealing information dashboards	• Guides purposeful color use for enhanced comprehension • Minimizes visual effects to focus on data presentation • Maintains consistent visual design across the dashboard
Visualization Technique	• Effective data visualization. • Use diverse chart types to effectively present information. • Visual display of important information.	• Determines data representation methods for effective communication. • Supports use of diverse chart types for optimal information display. • Enhances data interpretation through appropriate visual formats.
Layout	• Optimize screen space. • Balance information display.	• Optimizes screen space for information display. • Ensures balanced arrangement of dashboard elements. • Enhances readability and intuitive navigation.
Structure	• Simplify the design. • Provide context.	• Defines organization and hierarchy of dashboard elements. • Simplifies complex information through logical structuring. • Supports intuitive navigation between components.
User Interface	• User-friendly interfaces. • Use minimal graphical user interface (GUI) elements for effective interaction.	• Facilitates access to dashboard features and functionalities. • Enhances overall user experience and usability. • Serves as the primary interaction point between users and data.
Testing	• Test and validate dashboards for quality assurance. • Testing and evaluation	• Validates data accuracy and visualization correctness • Identifies and resolves usability issues pre-deployment • Ensures functionality meets requirements
Evaluation	• Testing and evaluation. • Deliver meaningful insights to users.	• Assesses dashboard effectiveness in delivering insights • Measures user satisfaction and dashboard performance • Identifies improvement opportunities
Continuous Improvement	• Iterative process and feedback. • Tailor best practices to the specific requirements of each domain.	• Enables ongoing refinement based on feedback. • Adapts to evolving user needs and business requirements • Creates optimization feedback loop for dashboard enhancement

TABLE VI. CATEGORIZATION OF THE BUILDING BLOCKS

Category		
Defining and Planning	***Design and Visualization***	***Testing and Improvement***
Building Blocks		
• Purpose • Audience • Data Source • Data Processing	• Style • Visualization Technique • Layout • Structure • User Interface	• Testing • Evaluation • Continuous Improvement

This systematic organization offers a clear pathway that guides dashboard developers from initial scoping to iterative enhancement. By structuring the building blocks in this way, the framework fosters a coherent understanding of how each component contributes to the overall dashboard architecture while reinforcing governance integration throughout the development process. The next section discusses how IG principles are embedded into the IDDO to strengthen compliance and ensure information quality.

B. Integrating Information Governance into IDDO

Embedding IG into the IDDO framework represents a key advancement in aligning dashboard design with quality, compliance, and accountability requirements. While IDDO adopts a structural modeling approach inspired by the BMO [12], the integration of IG principles differentiates it by embedding governance mechanisms directly into design logic and model semantics. This approach follows the Kernel Theory Fundamentalist perspective [34], [35], ensuring that the ontology is grounded in established theoretical foundations relevant to information systems design.

Effective dashboards rely on high-quality information, specifically, attributes such as accuracy, reliability, and security. Shortcomings in these areas can lead to misinterpretation or poor decision-making [39], [40]. Despite the critical role of information quality, dashboard design methodologies have often neglected the integration of formal governance principles. This study addresses that gap by embedding IG into the foundational layers of IDDO to support governance-aligned dashboard development.

The rationale for this integration stems from the limited linkage between IG and dashboard design in existing literature. This research responds by identifying core IG principles from established models and synthesizing them with practical dashboard design requirements, resulting in a tailored governance foundation suited to the information context of dashboards.

C. Deriving Key IG Principles for IDDO

The integration of IG principles into the IDDO is based on a structured synthesis of established IG models and relevant literature. Similar to the derivation of the twelve key building blocks of IDDO, this process ensures that the selected IG principles align not only with compliance and regulatory requirements but also with structured and user-centered dashboard development. As emphasized by Kooper et al. [41] and Smallwood [42], IG is not a one-size-fits-all framework. Although various studies have proposed IG principles [18], [21], [43], their applicability must be tailored to specific industries and information contexts.

Nasir et al. [44] highlight the difficulty in identifying universally applicable IG principles, reinforcing the view of Kooper et al. [41] and Smallwood [42] that IG selection should remain flexible and aligned with organizational objectives. An initial study by Nasir et al. [45] on unified information dashboard design identified common dashboard design principles that informed the selection of IG principles for IDDO. The adopted IG principles are drawn from two sources: 1) a synthesis of three established IG models and relevant literature to ensure governance and regulatory alignment, and 2) common design principles identified by Nasir, Ely Salwana, et al. [45] to ensure practical, user-centered governance. Based on this dual synthesis, Nasir et al. [44] proposed eight IG principles to serve as the foundational governance structure for IDDO, as illustrated in Fig. 3.

Fig. 3. Relevant IG principles as the foundational governance of the IDDO (Nasir et al. [44]).

After identifying the relevant IG principles, the next step was to map them onto the IDDO framework to strengthen the governance layer in dashboard design. The eight selected principles were chosen for their relevance and practical applicability in ensuring information quality, reliability, and security across diverse sectors. Each principle reinforces the integrity and traceability of dashboard components while supporting compliance with organizational and regulatory standards. Their inclusion aligns core design elements with established information management practices, particularly in sectors with stringent data requirements such as healthcare and financial services. Table VII summarizes the eight IG principles and illustrates how each supports IDDO's structural goals, enhancing governance alignment and dashboard reliability.

TABLE VII. SELECTED IG PRINCIPLES AND THEIR RELEVANCE TO IDDO

IG Principle	Core Function	Relevance to IDDO
Quality	Ensures information accuracy and timeliness	Supports reliable decision-making through accurate dashboard data
Security	Protects against unauthorized access	Safeguards sensitive information while maintaining data integrity
Accountability	Defines clear roles and responsibilities	Establishes ownership of information management processes
Transparency	Provides visibility into information handling	Builds user trust through clear data sources and processes
Compliance	Ensures adherence to regulatory standards	Enables tracking and reporting of compliance metrics
Integrity	Maintains data consistency from source to output	Preserves information consistency and prevents corruption
Availability	Ensures information accessibility	Supports real-time decision-making with timely access
Effectiveness	Measures dashboard alignment with objectives	Ensures actionable insights that fulfill organizational goals

The selection of these eight principles reflects not only their foundational role in IDDO but also their direct relevance to the diverse requirements of dashboard design across sectors. Embedding these principles within the IDDO framework strengthens the dashboard design process with robust governance mechanisms, ensuring that information remains accurate, secure, compliant, and valuable for knowledge-based decision-making.

After identifying the twelve building blocks and the eight relevant IG principles in this sub-section, these elements are integrated and formally presented using an ontological approach to establish the IDDO framework, the primary knowledge contribution of this study. The following sub-section will explore the development of the formalized IDDO framework in detail.

D. Establishing the IDDO Framework

This sub-section introduces the IDDO framework, the core artefact of this study, detailing its structure and formalization. As outlined in the methodology, IDDO was developed using the Unified Ontological Approach (UOA), an ontology development method (ODM) introduced by Nasir, Firdaus Sulaiman et al. [29], which systematically translates building blocks and IG principles into a formal structure tailored for dashboard design.

The adoption of ontology aligns with Gruber's [46] view of ontology as a specification of conceptualization, and with Noy and McGuinness's [47] emphasis on structuring domain-specific entities and relationships. Incorporating these foundations, the IDDO framework organizes components semantically with clearly defined relationships to support structured and reliable dashboard development, consistent with recent perspectives by Liu et al. [48] on formalizing complex information systems.

Inspired by frameworks like the BMO [12], IDDO is designed as a top-level ontology that dashboard designers across varying expertise levels can adopt, reflecting Guarino's [49] concept of a broad yet rigorous ontological structure. This balance ensures both usability and structural standardization.

The formalization of IDDO employs OntoUML, a modeling language grounded in the Unified Foundational Ontology (UFO) [36], [50], [51], enhancing semantic precision and conceptual clarity. OntoUML enables the explicit and consistent definition of dashboard components and interrelationships while embedding IG principles to ensure traceability and governance alignment.

Fig. 4 illustrates the formalized IDDO framework, integrating IG principles within a unified ontological model for dashboard design. Formalized using OntoUML and grounded in Unified Foundational Ontology (UFO) principles [52], the framework ensures conceptual clarity, structural consistency, and supports standardization, interoperability, and governance-aligned development practices.

OntoUML stereotypes represent ontological categories derived from UFO [50]. The ⟪kind⟫ stereotype defines rigid, identity-providing types (e.g., Purpose, Structure), while ⟪role⟫ captures anti-rigid types that may evolve over time (e.g., Data Processing). Intrinsic properties such as Style are modeled using ⟪mode⟫, temporal states like Testing and Evaluation are represented by ⟪phase⟫, and measurable attributes, including IG principles, are categorized as ⟪quality⟫. Component relationships are expressed through semantic links such as "characterizes", "influences", and "governs", ensuring accurate interaction modeling.

Structurally, Purpose (⟪kind⟫) characterizes Audience (⟪kind⟫), establishing dashboard context. Data Source (⟪datatype⟫) and Data Processing (⟪role⟫) manage information flow, while Style (⟪mode⟫), Visualization Technique (⟪kind⟫), and Layout (⟪kind⟫) define visual presentation. Structure (⟪kind⟫) organizes the architecture, and User Interface (⟪kind⟫) facilitates user interaction. Testing, Evaluation, and Continuous Improvement (⟪phase⟫) embed iterative mechanisms for quality and compliance.

Two superclasses ensure ontological validity: Processing Activity (⟪kind⟫) grounds Data Processing (⟪role⟫), and Quality Assurance (⟪kind⟫) supports quality-related phases, following Guizzardi's [36] principle that anti-rigid types must derive from rigid foundations to maintain identity criteria.

Eight IG principles (⟪quality⟫) are embedded: Effectiveness and Transparency guide design intent; Quality, Integrity, and Compliance ensure data trustworthiness; Security and Availability safeguard access; and Accountability underpins governance and traceability. This integration balances practical dashboard development with governance expectations.

Through this formalization, IDDO offers a rigorous and reusable design structure, integrating twelve dashboard building blocks, eight governance-aligned IG principles, and necessary ontological superstructures to ensure theoretical soundness and practical relevance. The next section outlines the evaluation process used to validate IDDO's structural and conceptual consistency.

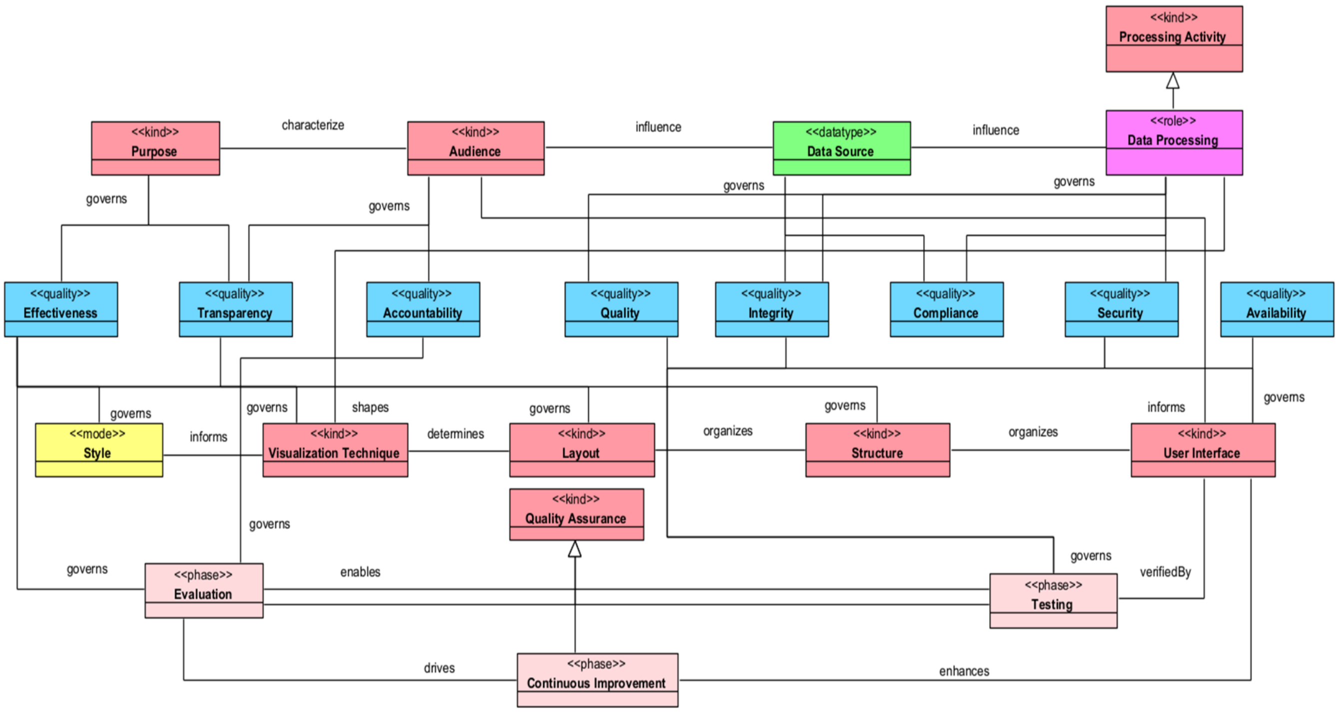

Fig. 4. The IDDO Framework.

E. Evaluation Result and Discussion

The evaluation of the IDDO framework employed a dual-method approach to ensure both structural and conceptual soundness, critical for standardizing dashboard design processes [53], [54]. Tool-based syntactic validation using the OntoUML Plugin was combined with a conceptual assessment grounded in Unified Foundational Ontology (UFO) principles.

While studies like Paul et al. [55] utilized competency-driven testing, this study emphasizes formal validation to establish IDDO's correctness during early development, consistent with best practices [52]. The OntoUML Plugin was chosen for its effectiveness in detecting structural inconsistencies, classification issues, and modeling violations that could undermine framework integrity.

Validation was conducted within the Visual Paradigm environment, systematically checking logical consistency across relationships, hierarchies, and component definitions [56]. The results confirmed IDDO's structural soundness and its suitability as a foundation for standardized dashboard development.

Parallel to syntactic validation, a conceptual assessment based on UFO criteria [36] evaluated component clarity, structural coherence, and relevance to real-world organizational contexts. The assessment verified that IDDO meets ontological adequacy standards and supports governance-aligned dashboard modeling.

Together, these evaluations confirm IDDO as a structurally valid and conceptually coherent ontology. As shown in Fig. 5, the validated framework demonstrates readiness to support standardized, governance-sensitive dashboard development across diverse settings.

This evaluation confirms the structural validity of the IDDO through rigorous tool-based assessment, laying a strong foundation for its progression to practical application. The syntactic validation performed using the OntoUML Plugin marks a critical milestone in the ontology development lifecycle, ensuring the framework's formal correctness prior to any implementation-focused evaluations. This approach reflects established practices in ontology engineering, where structural verification is prioritized before empirical testing [52].

The decision to emphasize tool-based validation at this stage was strategic, enabling the early detection and resolution of fundamental modeling issues that could otherwise undermine the framework's utility in practice. By first securing the ontological soundness and structural consistency of the IDDO, subsequent evaluations can be more confidently directed towards assessing its representational adequacy and practical applicability. Future work will broaden the evaluation scope to incorporate competency-based assessments and stakeholder validation, building upon the structurally verified foundation established here.

In addition to confirming IDDO's formal structure, the evaluation reveals three key implications for dashboard design practice. First, ontological formalization based on the UFO and implemented using OntoUML enhances semantic clarity and minimizes modeling ambiguities that often arise in ad hoc dashboard development. Second, embedding IG principles directly into the ontology promotes compliance-by-design, ensuring that governance is embedded into the system rather than retrofitted post-development. Third, the combined structural and conceptual validation affirms that IDDO provides a transferable foundation applicable across sectors, especially in contexts requiring traceability, reusability, and regulatory alignment.

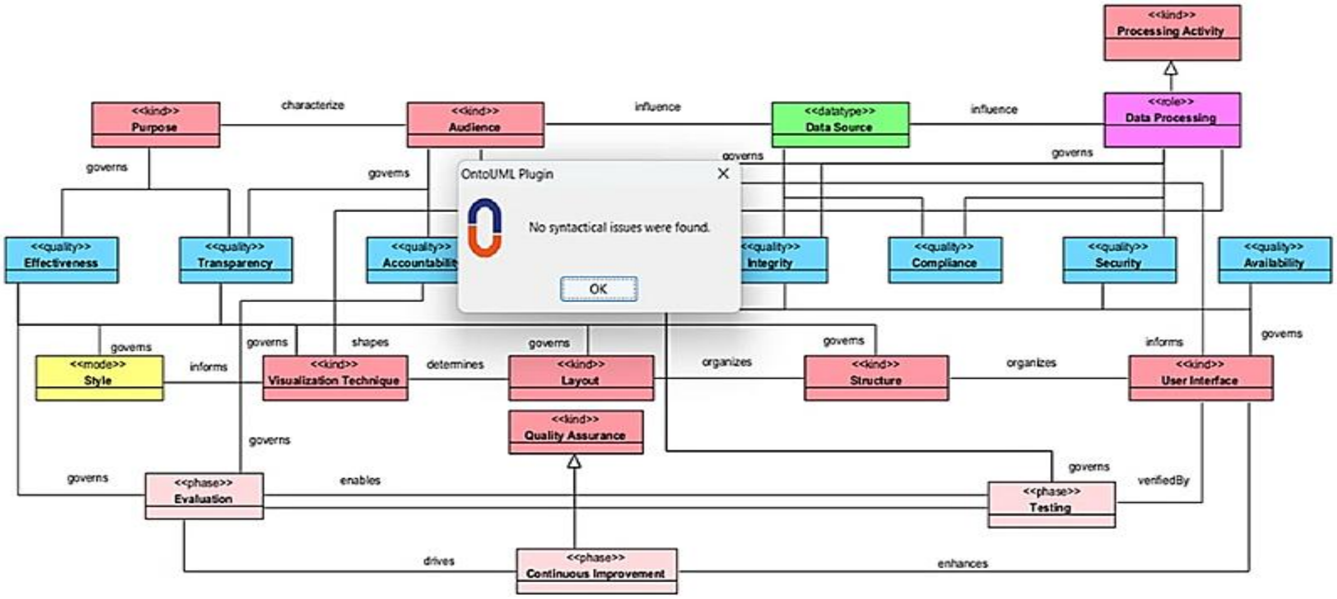

Fig. 5. Syntactical validation results of the IDDO framework.

While no empirical deployment was conducted at this stage, the structural soundness and conceptual completeness of IDDO offer strong theoretical grounding for its real-world application. These insights reinforce the practical relevance of IDDO and provide the rationale for its operationalization through the IDDM Canvas.

Building on this foundation, the following section introduces the IDDM Canvas as a practical design instrument that translates the formal ontology into a structured methodology. This transition from a formalized ontology to an applied methodology marks a crucial step in making governance-integrated dashboard design more accessible and actionable for practitioners across diverse organizational contexts.

V. Translating IDDO into IDDM Canvas

Though IDDO provides the conceptual backbone, the development of the IDDM Canvas marks a critical leap from theory to practice in dashboard design. Inspired by the translation of the BMO into the widely adopted BMC [28], the IDDM Canvas similarly operationalizes IDDO's building blocks and governance principles into a structured, user-friendly methodology.

The Canvas is organized into distinct design zones that mirror IDDO's core components, streamlining the process of dashboard planning, development, and governance integration. It offers a clear visual layout that guides practitioners, regardless of technical background, through each stage of dashboard creation, embedding conceptual rigor and compliance-oriented thinking along the way.

Each design zone clusters related building blocks, visually mapped to encourage collaboration, support structured decision-making, and promote early stakeholder alignment. This design ensures that governance principles are systematically embedded across the dashboard lifecycle, not treated as an afterthought.

By bridging the gap between theoretical modeling and operational needs, the IDDM Canvas enables organizations to apply IDDO principles with greater consistency, traceability, and strategic coherence. It acts as both a guide and a governance scaffold, helping teams design dashboards that are not only functional but also sustainable and auditable over time.

Fig. 6 presents the layout of the IDDM Canvas, illustrating how the twelve building blocks and eight IG principles are translated into an actionable design guide ready for real-world use.

While the IG principles are not explicitly visualized in the core layout of the IDDM Canvas, they are structurally embedded within the underlying IDDO framework as part of its governance foundation. As discussed earlier, IG does not act as a standalone building block but operates as a cross-cutting dimension that reinforces consistency, reliability, and compliance across dashboard development activities. This deliberate choice to omit IG from the visual Canvas was made to preserve clarity, particularly for non-technical users, while ensuring governance is enforced through structure rather than visual complexity.

This design strategy mirrors the approach taken by Osterwalder and Pigneur [28] in developing the BMC, which was adapted from the more detailed BMO [12].

In that transition, several conceptual and semantic elements, such as meta-relationships and formal dependencies, were intentionally abstracted out to enhance usability without compromising underlying rigor. Similarly, the IDDM Canvas abstracts IG elements while maintaining their operational influence through embedded logic and structural design.

A guided version of the IDDM Canvas is presented in Fig. 7, featuring instructional prompts for each design zone. These prompts provide practical support for users applying Canvas in real-world projects. Red text annotations further highlight specific areas where governance principles are applied, assisting both novice and experienced designers in creating structured, and compliant dashboards.

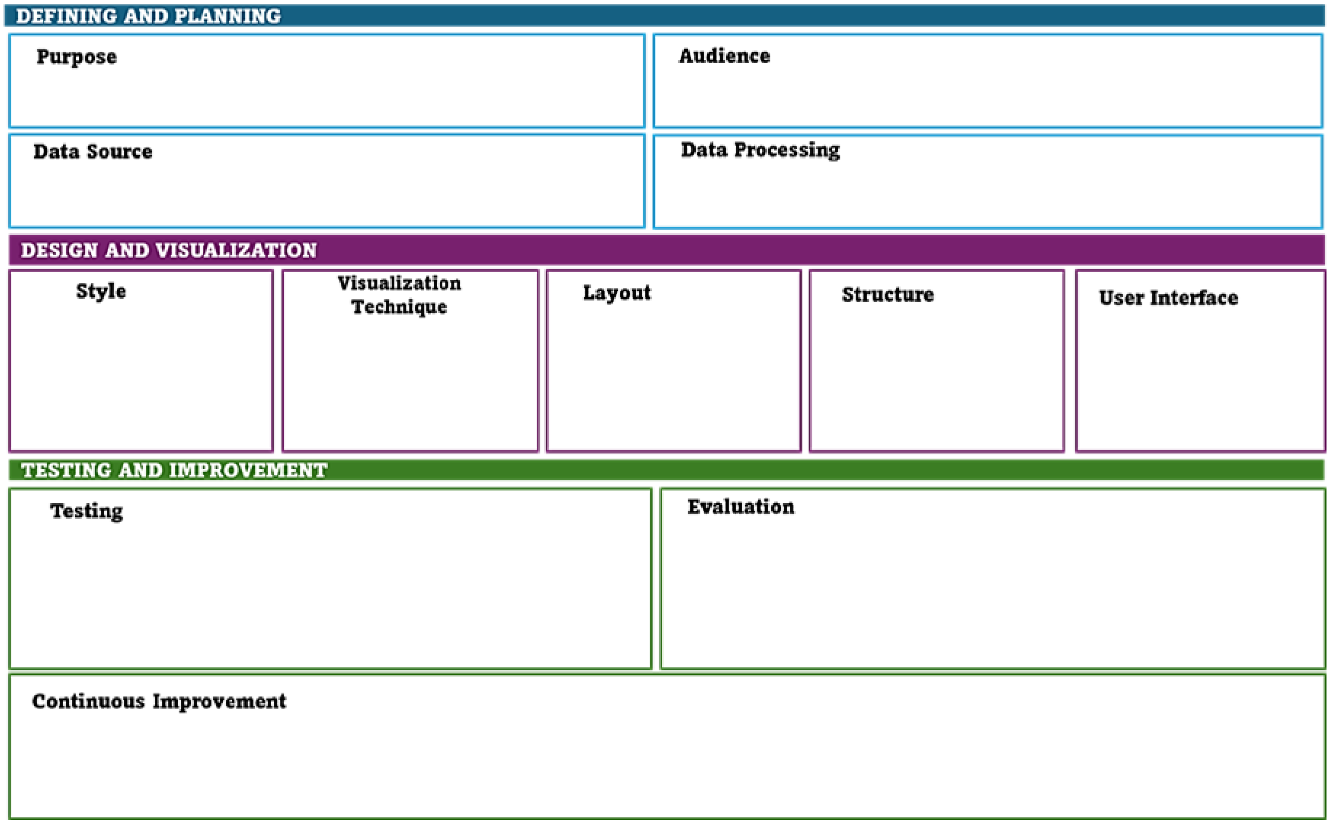

Fig. 6. The IDDM Canvas.

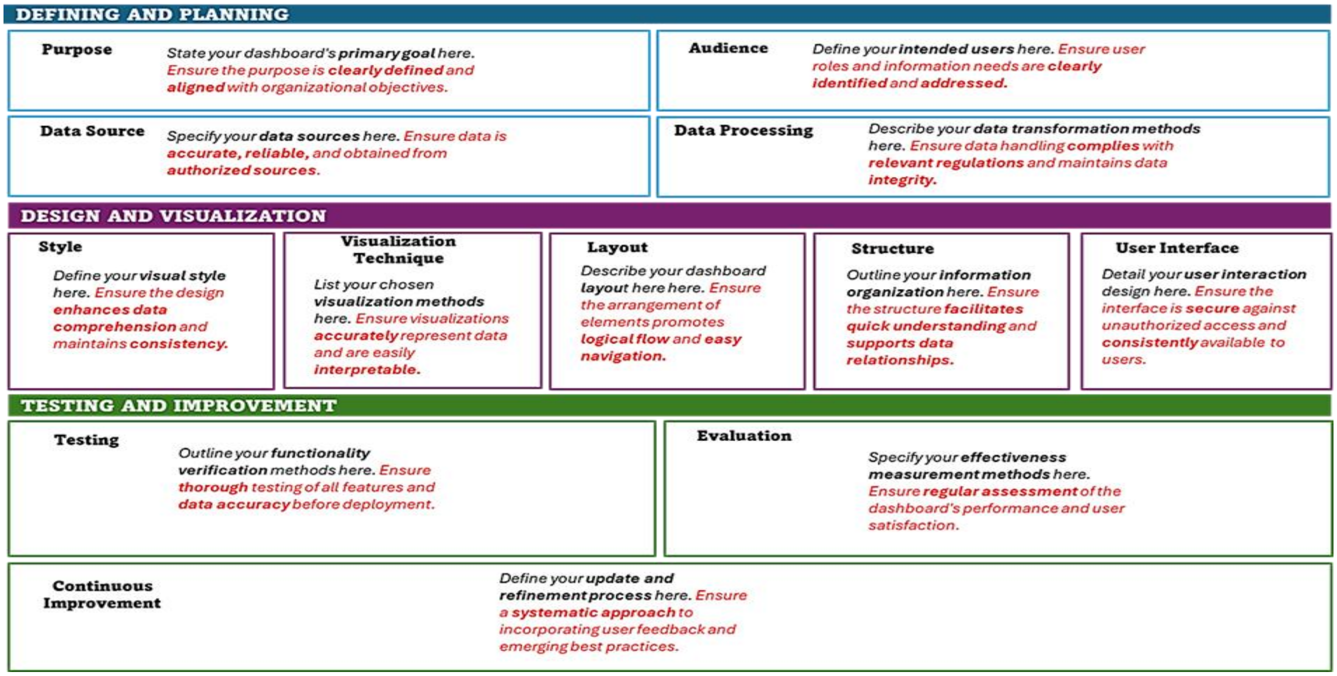

Fig. 7. The IDDM Canvas with instructional guidance.

As depicted in Fig. 6 and Fig. 7, the IDDM Canvas organizes its building blocks into three structured categories, offering a systematic pathway for dashboard development. In contrast to traditional dashboard approaches, which often depend on intuitive or ad hoc design methods, the IDDM Canvas provides a structured, repeatable methodology with governance principles embedded at its core. This structured approach enables organizations to develop dashboards that are not only semantically consistent but also compliant with established organizational standards [18].

TABLE VIII. IDDM CANVAS VERSUS CONVENTIONAL APPROACHES

Aspect	Conventional Dashboard Design	IDDM Canvas Approach
Methodology	Often ad hoc or linear; lacks structured guidance.	Based on a systematic, ontology-driven methodology with defined design building blocks.
Governance Integration	Rarely considers governance principles explicitly.	IG principles are embedded through the foundational IDDO framework and reflected in the design.
Scalability	Difficult to generalize across departments or organizations.	Modular and adaptable for cross-domain implementation.
Usability	Relies on designer intuition; inconsistent results.	Provides clear visual zones and guided prompts, improving consistency and collaboration.
Compliance and Traceability	Compliance requirements are often managed separately or retrofitted.	IG principles embedded from the start; design decisions are traceable and align with compliance standards.

Table VIII presents a comparative analysis between the IDDM Canvas and traditional dashboard design approaches, highlighting key differences in methodology, governance integration, scalability, usability, and compliance.

The IDDM Canvas acts as a practical implementation tool, translating IDDO's conceptual framework into a visual methodology that guides practitioners through a systematic dashboard development process. It facilitates collaborative design sessions by providing a common language and structure, fostering alignment among technical designers, domain experts, and governance stakeholders [42].

While IDDO has undergone tool-based validation, the IDDM Canvas has yet to be empirically tested in operational environments, limiting insights into its practical effectiveness. Future research should focus on applying the IDDM Canvas across diverse settings, supported by competency-based testing and stakeholder validation, to gather empirical evidence of its usability, adaptability, and governance alignment in real-world projects. Strengthening the empirical validation of the IDDM Canvas will be key to demonstrating its scalability and contribution to the broader field of governance-integrated information systems design.

VI. CONCLUSION

This study introduced two interrelated artifacts, the IDDO and the IDDM Canvas, to address the lack of standardized, governance-aligned methodologies in dashboard development. IDDO formalizes dashboard design through an ontological structure that integrates IG principles, while the IDDM Canvas operationalizes this structure into a practical, user-centric design tool. Together, they offer a scalable approach to enhance consistency, compliance, and effectiveness across diverse organizational contexts.

IDDO addresses three critical gaps in existing dashboard development practices: the absence of a transferable design methodology, limited application of ontological formalization, and weak governance integration. By combining twelve design building blocks with eight governance principles under a unified structure, IDDO provides a robust foundation for developing governance-compliant dashboards. Formal validation using the OntoUML Plugin confirmed its structural soundness and conceptual coherence.

Furthermore, the proposed IDDO framework and IDDM Canvas have strong practical relevance for organizations aiming to systematize dashboard development while embedding governance compliance by design. Recent recommendations highlight that effective dashboards must prioritize clarity, strategic alignment, and user relevance principles that are embedded in the IDDO structure [61]. Their application has the potential to significantly improve decision-support system reliability, accelerate dashboard deployment cycles, and enhance regulatory traceability.

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