

Knowledge Management foundations in the Design of the São Paulo State Institute of Weights and Measures (IPEM-SP) Quality Infrastructure Portal: Strategies and Challenges

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Abstract – This paper presents the conceptual, methodological, and technological foundations for a Knowledge Management (KM) model aimed at the digital transformation of the Quality Infrastructure (QI) ecosystem. As a case study, it examines the Quality Infrastructure Services Portal (PSIQ), currently under development by the Sao Paulo State Institute of Weights and Measures (IPEM-SP), at Technology Readiness Level 2 (TRL2). Using a qualitative, exploratory, and applied approach, the study supports the transition of the portal to TRL3. Classical KM models (SECI, DIKW, APO, and Cynefin) are employed to structure knowledge flows, while enabling technologies—such as Intelligent Virtual Assistants, Semantic Search, Big Data & Analytics, and Robotic Process Automation—are mapped to sustain operationalization. The results indicate that PSIQ can function as a cognitive digital platform for regulatory knowledge, institutional memory, interoperability, and strategic learning. The paper concludes with recommendations to consolidate KM as a strategic function in the digital transformation of QI in Brazil.

Palavras-chave: Knowledge Management; Quality Infrastructure; Digital Transformation.

I. INTRODUCTION

Digitalization is a strategy that holds the potential to foster the efficiency of public policies and the provision of public services [1]. In Brazil, its application within Quality Infrastructure (QI)—a system composed of institutions, policies, legal frameworks, and practices that ensure the quality, safety, and environmental integrity of goods and services—directly impacts components such as metrology, standardization, accreditation, conformity assessment, and market surveillance [2].

In this context, the Institute of Measures and Weights of State of São Paulo develop initiatives focused on the digitalization of Quality Infrastructure (QI) to enhance industrial competitiveness, facilitate access to technical information, and promote integration within the productive ecosystem. Among these initiatives, the Quality Infrastructure Services Portal (QISP) stands out as an intelligent digital platform designed to organize,

systematize, and disseminate normative content associated with the services provided by the institution.

This paper explores the conceptual, methodological, and technological foundations that should underpin Knowledge Management (KM) at QISP. In a technical-regulatory environment such as that of Quality Infrastructure (QI), effective KM [3] requires more than mere storage: it demands the organization and dynamization of various types of institutional knowledge—technical-regulatory (standards, regulations), operational (inspection routines, service instructions), and tacit (expert experiences). The importance of updating routines, emerging technologies (AI, Semantic Search, RPA), complementary tools (ontologies, ECM, visual analytics, digital competencies management), and curation strategies aligned with the institutional mission is also highlighted.

One of the foundational concepts underlying this study is the Technology Readiness Levels (TRLs) framework. Originally developed by NASA to evaluate the maturity of emerging technologies within aerospace programs, TRLs comprise a structured scale of nine incremental stages—from TRL 1, in which basic scientific principles are observed, to TRL 9, where the technology is demonstrated to operate successfully in its target environment [4]. This framework offers a systematic and consistent approach for assessing the developmental stage and readiness of technological solutions. To facilitate understanding of these maturity levels, Figure 1 presents the full TRL structure and its corresponding descriptions.

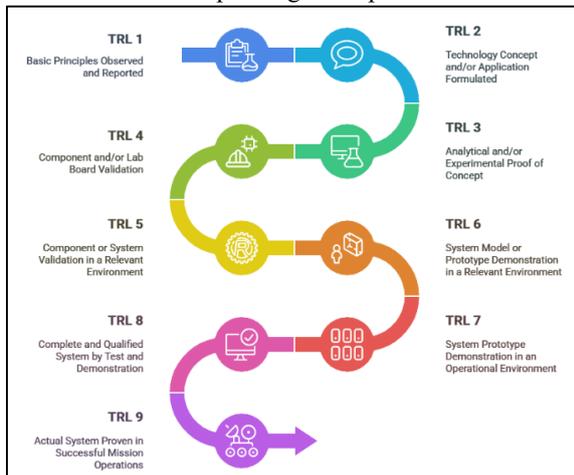


Fig. 1. Stages of Technology Readiness Levels (TRLs)

Currently at TRL 2 (technological formulation), the project requires the definition of structural principles, functional requirements, and enabling technologies. The transition to TRL 3 (experimental validation) depends on a clear methodological approach in designing knowledge

flows, curation mechanisms, and interoperability criteria among systems and technical databases.

The central problem lies in structuring, already at TRL 2, the elements that enable the conversion of tacit, explicit, and automated knowledge into a strategic asset. Accordingly, the paper seeks to answer the following research question: how can KM foundations be structured to support the design of QISP and prepare it for TRL 3, ensuring continuous organization, dissemination, and updating technical-regulatory knowledge?

The approach combines classical KM theoretical models with the portal's technological components, modelling knowledge flows, identifying challenges, and proposing recommendations for its future evolution. The research adopts a qualitative, exploratory, and applied approach, focused on technological formulation and the conceptual modelling of the main informational and cognitive elements.

To this end, the paper is structured as follows:

Section II: the articulation between QI and KM, current gaps, and the role of digital platforms.

Section III: the main theoretical models of KM.

Section IV: the technological strategies of QISP and their connection with KM.

Section V: the methodology for analysis and preparation for TRL 3.

Section VI: the challenges and opportunities of KM at QISP.

II. QUALITY INFRASTRUCTURE AND KNOWLEDGE MANAGEMENT: EMERGING INTERSECTIONS

Digital transformation in public administration has driven the adoption of emerging technologies to modernize services, increase transparency, and strengthen institutional capacity. In the context of Quality Infrastructure (QI), this movement promotes the digitization of technical processes, the integration of regulatory systems, and democratic access to technical regulatory knowledge [5].

In this scenario, Knowledge Management (KM) becomes a foundational element in the digital transformation of QI. In sectors such as metrology, standardization, and conformity assessment, KM underpins the capture, systematization, updating, and dissemination of critical information—from technical standards and legal requirements to operational instructions and oversight guidelines—whose continuous curation ensures traceability and regulatory confidence.

An effective KM system integrates people, processes, and technology, fostering alignment between institutional knowledge and organizational objectives [6]. At QISP, developed by IPEM-SP, the goal is to transform this knowledge into a structured digital asset that guides users

in their technical and legal obligations. This requires more than just digitizing documents; it demands information flows oriented toward usability, interoperability, and continuous updating.

However, according to the Final Report of the Public Subsidies Initiative of the National QI Strategy (ENIQ), significant structural challenges persist: deficiencies in governance, a lack of resources for modernizing the national conformity mark, and limitations in the Brazilian Conformity Assessment System (SBAC). These issues are compounded by the low participation of the private sector in standardization, the regional concentration of services, insufficient investments in laboratory infrastructure and technical training, as well as excessive bureaucracy and disjointedness between standardization and regulation [7].

These limitations call for digital solutions to consolidate and streamline regulatory knowledge flows. Platforms such as QISP, by incorporating technologies like Intelligent Virtual Assistance, Semantic Search, Big Data, and Robotic Process Automation (RPA), do not merely provide information but also structure the governance of technical-regulatory knowledge. These technologies enable intelligent screening, contextualized retrieval of norms, automated responses, and data-driven analyses.

By promoting an institutional culture centered on data curation, interoperability, and continuous learning, these platforms reinforce QI as an integrated system. Their adoption fosters responsive regulation and voluntary conformity, enhancing the effectiveness of public actions and the competitiveness of the productive sector.

Thus, the intersections between QI and KM represent a strategic field for institutional modernization. QISP stands as a concrete opportunity to apply KM principles in a digital regulatory environment, functioning as an institutional laboratory for modeling replicable solutions within Brazil's National System of Metrology, Standardization, and Industrial Quality.

III. KNOWLEDGE MANAGEMENT MODELS FOR TECHNICAL-REGULATORY ENVIRONMENTS

The formulation of a Knowledge Management (KM) model for the Quality Infrastructure Services Portal (QISP) requires a foundation in well-established theoretical frameworks capable of guiding the systematization, curation, and dissemination of technical regulatory content in complex digital environments. This theoretical basis is especially relevant at TRL 2, which focuses on conceptual and technological structuring, ensuring that institutional knowledge is transformed into a reusable, accessible digital asset aligned with the public mission of QI.

The SECI model describes the mechanisms for converting tacit to explicit knowledge through four

processes: socialization, externalization, combination, and internalization [8]. At QISP, it contributes to transforming the knowledge of QI experts into structured digital artifacts, such as regulatory flowcharts, FAQs, manuals, and technical protocols. Once systematized, these contents become accessible repositories for both internal and external users, enhancing access to qualified knowledge.

The DIKW hierarchy (Data, Information, Knowledge, and Wisdom) organizes informational complexity into a semantic chain [9]. At QISP, it structures the process from the collection of raw data (e.g., technical records), through the transformation into organized information, to the generation of useful knowledge for normative interpretation and decision-making. This hierarchy supports the definition of logical layers in information architecture.

The methodology of the Asian Productivity Organization (APO), with its five pillars—leadership, people, processes, technology, and results—guides KM in public institutions [10]. When applied to PSIQ, it fosters performance indicators, continuous feedback, and quality control of content, which are essential for the transition to TRL 3, where evidence of viability is required.

Snowden's Cynefin model classifies decision-making contexts as simple, complicated, complex, or chaotic. At PSIQ, it enables distinguishing between demands that can be automated (e.g., standardized norms) and those requiring specialized analysis (e.g., normative exceptions), thereby optimizing the combined efforts of virtual assistants, human curators, and semantic algorithms.

The KM Maturity model identifies an organization's evolutionary stage—from informal practices to a consolidated KM culture—allowing the portal's functionalities to be calibrated according to institutional maturity [11].

The integration of these models results in a complementary theoretical framework. KM Maturity assesses the level of KM maturity; SECI addresses the conversion of knowledge; DIKW structures informational complexity; APO guides governance; and Cynefin defines appropriate cognitive responses. This combined framework supports a robust KM system for QISP, catalysing the digital modernization of QI in Brazil.

IV. TECHNOLOGICAL STRATEGIES AND THEIR CONNECTION WITH KNOWLEDGE

The development of a Knowledge Management (KM) model in Quality Infrastructure (QI) requires technologies capable of structuring and energizing technical-regulatory information flows. In the case of the Quality Infrastructure Services Portal (QISP), KM demands more than a mere digital repository; it requires technological architecture based on accessibility, continuous updating, interoperability, and intelligent curation [3].

Among the essential technologies, Intelligent Virtual Assistance—based on Natural Language Processing (NLP) stands out as a mediator between users and normative content. Well-trained chatbots simulate human interactions and provide precise, contextualized responses, thereby reducing informational bottlenecks and democratizing access to institutional knowledge [12].

Advanced Semantic Search goes beyond keyword-based retrieval by integrating context, user intent, and conceptual synonyms [13]. This approach is critical in QI, where technical terminology varies according to the regulated sector, resulting in a more responsive and inclusive information architecture.

Big Data and Analytics enable the generation of knowledge from large volumes of structured and unstructured data. By identifying patterns, anticipating demands, and feeding back into decision-making processes, these tools reveal frequent inquiries, norms with high non-compliance, and priority topics [14].

Robotic Process Automation (RPA) supports the operationalization of KM by automating repetitive tasks such as document indexing, standardized responses, and metadata updating. This automation liberates human resources for curation activities and reduces errors, promoting scalability and standardization [15].

Additional complementary technologies enrich the KM ecosystem. Technical ontologies foster interoperability between systems and knowledge domains, while Enterprise Content Management (ECM) systems ensure version control, traceability, and document approval processes. Visual analytics tools, including dashboards and dynamic panels, facilitate the monitoring of KM effectiveness [16].

Equally important is the management of digital competencies, which connects institutional knowledge and human development. Solutions that map skills, provide learning pathways, and promote technical-regulatory upskilling reinforce the sustainability of KM as an organizational practice.

The strategic distinction between essential technologies (focused on operations) and complementary ones (aimed at quality and sustainability) consolidates QISP as an adaptive, data-driven platform with embedded institutional intelligence. Consequently, the technological infrastructure of QISP should be understood as a cognitive platform focused on organizational learning, decision traceability, and regulatory transparency. In a dynamic and demanding environment, the integration of these technologies is indispensable for establishing KM as a strategic function in digital QI.

V. METHODOLOGY FOR STRUCTURING AND PREPARATION FOR TRL3

The nature of this study, centered on the conceptual and technological analysis of Knowledge Management (KM) in Quality Infrastructure (QI), demands a methodological approach that integrates theory, modelling, and application. For exploratory and applied purposes, the research aligns with the logic of projects in the technological formulation phase (TRL 2), aiming to support the transition to TRL 3 (experimental validation).

The approach is qualitative, focused on constructing interpretative and propositional knowledge. It is based on the understanding and systematization of complex phenomena—such as the curation of technical-regulatory knowledge in digital environments—drawing on multiple sources and the integration of theoretical models, institutional practices, and emerging technologies [17].

The envisioned methodology is organized into three integrated axes:

1. Requirements Review and Architecture Analysis In this phase, the requirements of QISP are analysed, with an emphasis on functional flows and the types of knowledge involved: tacit (expert experience), explicit (normative documentation), and automated (algorithmic responses). Traditional QI communication is compared with the flows envisioned for the portal, identifying changes in accessibility, interoperability, and reliability [3]. Conceptual diagrams are also developed using tools such as Napkin AI, graphically representing the transformation of regulatory information into reusable knowledge and identifying the system's points of entry, mediation, and output.

2. Simulation of Cognitive Flows Applied to KM In this stage, use scenarios for QISP are modelled based on four strategic technologies: Intelligent Virtual Assistance, Semantic Search, Big Data/Analytics, and Robotic Process Automation (RPA). For each technology, micro-cycles of KM are designed to demonstrate: the capture of demands and semantic intent (chatbot); contextualized retrieval (semantic search); pattern identification (analytics); and task automation (RPA) [12][14]. These simulations test, in a controlled environment, the integration between technological modules and KM guidelines, particularly regarding the updating and dissemination of regulatory content.

3. Proposition of Criteria for TRL 3 Based on the previous stages, the minimum criteria for transitioning QISP to TRL 3 must be identified. These include: the existence of a conceptually validated digital KM model with defined flows and actors; the implementation of automated routines for capturing, updating, and disseminating normative content; measurement of system responsiveness and assertiveness based on indicators such as response time, semantic adherence, and resolution rate; and the definition of a pilot

testing plan with real users, covering diverse profiles (technicians, entrepreneurs, consumers) and various regulatory themes.

These strategies are essential for consolidating a methodological model capable of supporting the experimental validation of QISP as a KM platform applied to QI, in accordance with TRL 3 requirements.

In this context, considering all the aspects outlined in the study, Figure 2 illustrates the proposed structural foundations for Knowledge Management in QISP—a comprehensive representation of the cognitive operational logic and the digital resources that underpin the portal’s proposal.

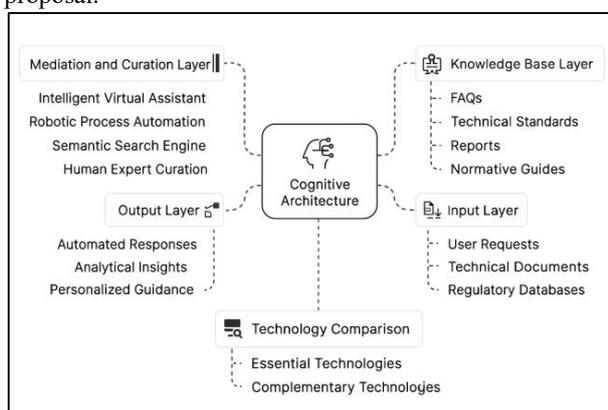


Fig. 2. Cognitive and technological architecture for knowledge Management in PSIQ.

The organization is structured into four interdependent layers: data inputs, which encompass user demands, technical documents, and external normative databases; mediation and curation mechanisms, composed of technologies such as Intelligent Virtual Assistance, RPA, Semantic Search, and specialized curation; a structured knowledge base, where organized normative content, decision flows, and digital repositories are consolidated; and, finally, strategic outputs, corresponding to the delivery of automated responses, predictive analytics, and personalized guidance to users.

Figure 1 also clarifies the distinction between essential and complementary technologies, highlighting how each is positioned and contributes to the governance of technical regulatory knowledge. Thus, it serves as a visual synthesis of the dimensions addressed in Sections III, IV, and V, designed to support the system’s conceptual modelling and guide its transition to more advanced levels of technological maturity.

VI. CONCLUSION AND RECOMMENDATIONS

This research explored the conceptual, methodological, and technological foundations required to structure a Knowledge Management (KM) model for the Quality Infrastructure Services Portal (QISP), currently at TRL 2.

It demonstrated that the digitization of Quality Infrastructure (QI) requires integrated approaches to transform technical-regulatory knowledge into accessible, updatable, and interoperable assets.

The theoretical analysis revealed that models such as SECI, DIKW, APO, and Cynefin are highly applicable to PSIQ because they enable the conversion of knowledge, the organization of information flows, the alignment of institutional strategies, and the guidance of responses to diverse regulatory contexts. These models underpin KM flows based on human curation, automation, and responsiveness.

In the technological field, four central resources stand out—Intelligent Virtual Assistance, Advanced Semantic Search, Big Data & Analytics, and Robotic Process Automation (RPA)—as fundamental tools for organizing, updating, and disseminating technical knowledge. Complementary technologies such as ontologies, ECM, visual analytics, and digital competencies management further reinforce the sustainability and governance of KM in the digital QI environment.

The proposed methodology demonstrated that preparing for TRL 3 requires more than technical advancement: it is necessary to validate the knowledge architecture, model semantic flows, simulate usage scenarios, and establish evaluation criteria for system maturity. The challenge is to build not only a portal, but also a cognitive platform focused on decision traceability, regulatory transparency, and organizational learning.

Some persistent obstacles include institutional fragmentation, the lack of inter-institutional curation mechanisms, the absence of standardized technical vocabularies, and cultural challenges related to adopting AI-based solutions. However, these barriers also open opportunities for strategic initiatives, such as strengthening IPREM-SP role in digital regulation, expanding access to normative information for micro and small enterprises, and fostering a collaborative KM ecosystem among Sinmetro agencies.

It is recommended that the next project stages include: (i) empirical validation of the simulated flows; (ii) participation of QI specialists in curation and in training the intelligent systems; (iii) use of performance indicators (accuracy, responsiveness, and usability); and (iv) feedback mechanisms based on user interactions.

In conclusion, QISP can consolidate itself as a strategic KM platform in Brazilian QI, provided that its digital architecture is based on scientific foundations, recognized models, and interoperable, adaptive technologies. In advancing in this direction, the portal will not only digitize processes, but also transform the production, mediation, and reuse of regulatory knowledge in the public sector.

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