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Empirical Research Article

Digital Collaborative Network Architecture Model Supported by Knowledge Engineering in Heritage Sites

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Abstract

The objective of this article is to create a model of integrated management from the framework modeling of a digital collaborative network supported by knowledge engineering to make heritage site in the Brazil more effective. It is an exploratory and qualitative research with thematic analysis as technique of data analysis from the collaborative network, digital platform, world heritage, and tourism themes. The snowballing approach was chosen, and the mapping and classification of relevant studies was developed with the use of the spreadsheet tool and the Mendeley® software. The results show that the collaborative network model oriented towards strategic objectives should be supported by a digital platform that provides a technological environment that adds functionalities and digital platform services with the integration of knowledge engineering techniques and tools, enabling the discovery and sharing of knowledge in the collaborative network.

Keywords:

tourism destination; digital collaborative network; knowledge engineering; world heritage

1. Introduction

The intertwining of tourism and culture, especially in tourist activities at artistic, archaeological, and cultural heritage sites, is a significant pathway to global sustainable development (UNWTO, 2018). Heritage tourism not only multiplies tourism product and service production but also boosts investment in both national and local tourism industries (Chong & Balasingam, 2019). For many developing countries, small historic cities heavily depend on their cultural and natural heritage as key drivers of economic and social progress (Yang & Wall, 2021).

Heritage represents all that is believed to have been passed down from the past. While not all legacies from nature and culture are universally seen as desirable, heritage is nonetheless regarded as a valuable, irreplaceable resource, crucial for personal and collective identity and self-respect (Lowenthal, 2006). Heritage encompasses both material and cultural legacies, extending to a range of tangible and intangible assets that are part of our everyday lives and inherited from our ancestors (Barretto, 2019). Intangible refers to the differentiation between tangible and immaterial or intangible assets.

Brazil ranks 13th among the 167 member states in terms of World Heritage sites, with 21 additional nominations for heritage recognition (UNESCO, 2021). Most of the country's cultural World Heritage Sites (WHS) are historic centers from the colonial era, including architectural works and archaeological sites, primarily in the northeast and southeast regions. Its notable natural assets also make Brazil a global leader in nature and culture (WEF, 2019).

Despite its vast potential due to diverse natural and cultural resources and competitive pricing, Brazil is yet to become one of the most competitive tourist destinations, ranking 32nd in the Tourism and Travel Competitiveness Index due to inadequate tourism infrastructure (WEF, 2019).

The Brazilian government, through the National Tourism Plan (PNT) 2018-2022, aims to strengthen tourism regionalization, enhance quality and competitiveness in the sector, foster innovation, and promote sustainability (BRASIL, 2019a).

The 2018-2022 PNT includes strategies such as enhancing the national tourism offerings by: (1) promoting the appreciation of cultural and natural heritage for tourism; (2) developing smart tourist destinations; and (3) fostering segmented growth in the country's tourism products (BRASIL, 2019a).

Observing the situation of cultural and natural World Heritage (WH) sites in Brazil, the Brazilian Federal Court of Auditors (TCU) conducted a study that highlighted problems that prevent the country from achieving and exploring all the potential benefits of UNESCO recognition (BRAZIL, 2017). As part of the responses to the Federal Court of Auditors, the Ministry of Tourism proposed in 2018 the development of the National Program for Cultural and Natural Tourism.

The TCU conducted an audit (Case TC-030.814/2015-4) to assess the federal management of these assets and their use for tourism (BRASIL, 2017). TCU identified significant shortcomings in public administration and major management issues, hindering the country from fully leveraging the benefits of UNESCO recognition. Key findings included, according to TCU (2015): i) absence of cohesive and collaborative management among the agencies overseeing these sites; ii) lack of cooperative agreements and existing conflicts between involved entities; iii) insufficient data and information for action development and monitoring; and iv) the absence of a national policy that prioritizes World Heritage sites in tourism strategies.

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This is the challenge that Brazil has to solve because, despite having 25 WH sites, the country faces socioeconomic and environmental sustainability problems (Goffi et al., 2019) and the lack of a consistent dialogue with disruptive innovation (Carneiro & Nascimento, 2017).

The objective of this article is to present the integrated management model from the framework modeling of a digital collaborative network supported by knowledge engineering to reach the results proposed in the National Program for Cultural and Natural Tourism. It conditioned to a strategic macro-action regarding the creation of a National Network of Sites of World Cultural and Natural Heritage as an instrument of collaboration and co-creation for the development of discussions of common interests and transversal integration of various public and private organizations based on engineering and knowledge management (UFSC, 2020).

2. Collaborative Networks for Tourism

Collaborative networks are not just communication mechanisms, but platforms to help advance collective understanding, providing an environment for organizational sensemaking. An environment where organizations can create synergies, allowing participants to build on each other's ideas, deepen their thinking and understanding, and ultimately result in innovation (Cormican & Dooley, 2007).

The primary goal of setting up a collaborative network is to model a form of organization or a system of organizations. The systemic nature of such a structure imposes many technical and socio-organizational challenges. In the scope of a collaborative network, the modeling framework can range from a more generic level to more specific and concrete ones. For this, one can use some modeling structure such as the one based on a metamodel and create model instances to represent this knowledge.

Based on the concept of metamodeling, it is a modeling framework for collaborative situations, developed by Benaben et al. (2017). They mapped some basic principles of corporate and systems modeling and structured it according to four main dimensions: context, partnerships, goals, and behavior.

2.1 Collaborative Digital Platforms

Digital platforms have become the main configurations of value co-creation. Market trends driven by digitalization, new forms of interactions and information exchanges have given rise to business models and open innovation strategies, generating a major impact on knowledge and data intensive activities (Bereznoy et al., 2021; Gansen et al., 2018; Zutshi & Grilo, 2019). The logic of the collaborative platform is to serve as an intermediary base upon which collaboration can be built among stakeholders. According to Pilving et al. (2021), it is where collective and individual identities interact, shape the scope of collaboration, and create linkages for individual or collective gains.

Collaborative networks must have four characteristics, i) the presence of a group of heterogeneous, independent and selected members who demonstrate a collaborative attitude; the presence of at least one common goal, which is critical to the success and survival of member; iii) the need for an organized structure and system of rules for coordinating interactions and activities; iv) the need for a negotiation and agreement process (Bonomi et al., 2020).

The development of a digital platform involves a process perspective in planning and managing strategic decisions and choices. Fürstenau et al. (2019) developed a platform planning and management framework that is based on four strategic premises of multilateral digital platforms (Table 1).

Table 1. Set of strategic practices for digital platforms

Planning and Management Extension	Scope and related tasks
Develop a strategy and governance model	Develop a strategy and vision for the platform. Design a business model and governance structure.
Design the technological architecture and standards selection	Design a technological architecture. Configure development priorities. Architect a foundation for interoperability and usage standards
Facilitate participation and community building	Facilitate the development segment of the platform´s applications. Promote community building around the platform (through events and knowledge sharing).
Promote engagement with platform ecosystem and broader environments	Formation of alliances based on choices of business and technical standards. Establish dialogue with other platforms, external to the ecosystem.

In general, platforms empower flexible and dynamic digital businesses, and these businesses create new business models by bridging the boundaries between the digital and physical worlds due to the convergence of people, business, and things. The new digital businesses lead organizations to evolve into projects with greater flexibility as opportunities arise and thus a coevolution to digital platform ecosystem occurs (Gansen et al., 2018; Yablonsky, 2020).

Digital platforms are created and perfected on a technological infrastructure composed of a set of computational and network resources that allow multiple parties or agents to orchestrate their services and content needs (Constantinides et al., 2018). Using selective combinations of modules, digital platforms can range from a simple architecture to more complex environments, where developers can create and deliver their digital add-ons aimed directly at the customer or to strengthen a business strategy (Zutshi & Grilo, 2019).

Zutshi and Grilo (2019) proposed a conceptual architectural model based on for layers:

• Business layer: defines the business models that promote engagement between actors in an ecosystem. The design of an ecosystem must ensure that each participant receives a fair deal while operating on the platform;

• User interaction layer: related to human-machine interface producers and consumer engagement with the platform. As new technologies emerge, new input and output interfaces become very relevant;

• Development layer: allows third-party developers to create add-ons such as applications products or services. Developer tools are vital components of the platform and often have their own programming language and interfaces;

• Integration layer: allows the digital platform to interface with several other software units, such as data processing unit, external analytical system, data sources, payment gateways and advertising services.

But it´s necessary to be integrated with knowledge engineering solutions for the knowledge sharing process across the platform.

3. Knowledge Engineering in Collaborative Networks

Knowledge representation is incorporated through standardized languages, metadata, and ontologies, or through semantic networks and other non-formal forms. The ability to integrate knowledge from different sources is achieved due to the characteristics of graphs, linking and materializing them in one place and in diverse formats. Knowledge production occurs through the ability to deduce through, for example, logical reasoners and neural networks; to learn through new data and

algorithms; and to generate knowledge through refined queries (Arenas et al., 2021).

The representation of this type of knowledge is one of the main activities of Knowledge Engineering, which is concerned with modeling activities that consist of an implementation-independent specification of knowledge in an application domain. Modeling provides the requirements for building knowledge systems (Speel et al., 2001), that are intended to manipulate organizational knowledge, stored and redistributed as organizational memories acquired from organizational members (Weber et al., 2001).

Knowledge assets need to be stored in a structure way using techniques that include the use of meta tags, standardization, annotation, classification, search optimization and retrieval (Evans et al., 2014). Application of semantic metadata to knowledge assets can also be used to facilitate sharing, promoting the creation of new knowledge assets and collaborative adherence (Pellegrini, 2017).

Other action is the application of Semantic Web (SW) principles to metadata standards, using schemes such as the Resource Description Framework (RDF) and the Web Ontology Language (OWL) which provide support for automated processing of data. Knowledge enables humans and machines to share tasks through the reasoning that both produce (Leger et al., 2006). In collaborative activities, SW can be used in the Knowledge Discovery Process (KDD) and Data Source Mining (DSM), where SW and ontologies help in the data selection, pre-processing, transformation, mining, and interpretation/evaluation phases (Ristoski & Paulheim, 2016).

Finally, another issue regarding knowledge modeling corresponds to the current situation in which it is strongly affected by the production of big data and artificial intelligence (AI) technology (Benaben et al., 2020). The production of big data accentuates the need to leverage NoSQL technology for descriptive and predictive learning. Systems integrated with a semantically encoded knowledge base using on semantic rules are fundamental tools in the representation and creation of collaborative knowledge (Naeen et al., 2016).

4. Methodology

This research was conducted using the Design Science Research Methodology (DSRM) process model by Vaishnavi et al. (2017). The process for conducting research through DSRM is oriented toward solving a class of specific problems that are relevant to organizations (Dresch et al., 2015). DSRM model consists of six activities, i) identification and motivation of the problem, ii) definition of objectives for the solution, iii) design and development, iv) demonstration, v) evaluation, vi) communication (Dresch et al., 2015). But in this paper, four steps were used, which will be presented below.

The systematic literature review process was based on Petticrew and Roberts (2006). The literature review of this study involved a set of terms related to collaborative and inter-organizational networks, digital platform, engineering and knowledge management, world natural and cultural heritage, and tourism. The documental analysis combined with the search and review of publications was characterized by an interpretative qualitative research perspective with the use of a thematic analysis approach defined as the Framework Method to conduct a cross-sectional analysis using a process of abstraction and description of the data (Gale et al., 2013; Goldsmith, 2021).

4.1 Research Background

This research was based on a documentary analysis of national legislation and regulations. It highlights three strategic documents:

• Audit by the Federal Court of Accounts (TC-030.814/2015-4) resulted in Ruling No. 311/2017. The Audit Report was crucial in identifying the lack of an integrated tourism management model for Brazilian World Heritage sites and the absence of specific public policies in this sector.

• Presidential Decree No. 9763/2019 established a specific policy for managing tourism at Brazil's World Heritage Sites. It underlined the necessity of developing management models through coordination and the creation of collaborative networks.

•

Preliminary Proposal for the PNTCN and Proposal for Expanding the Tourism Business Platform developed by the UFSC's Departm ent of Knowledge Engineering, these preliminary projects empha sized the need for a collaborative digital platform. This platform would facilitate the articulation and functioning of the National N etwork of World Heritage Sites in Brazil.

4.2 Literature Review

The research involved two main stages of literature review: the first between March and April 2021, and a second in December of the same year. This was to enhance the understanding of tourism management requirements at Cultural and Natural WHS, aligning with the recommendations from the board's evaluators. The goal was to conduct an in-depth study of the shortcomings in WHS management and the necessity for collaborative networks, supported by current references.

Key academic databases such as Scopus, Web of Science (WoS), Scielo, ScienceDirect, and Google Scholar were extensively searched. Additionally, gray literature, including reports from the European Union, UNWTO, and UNESCO documents, was also reviewed to provide a comprehensive perspective. The research process was iterative, constantly evolving to better define the problem based on existing literature, as it was driven by a practical issue.

Selection of publications was guided by specific inclusion and exclusion criteria based on integrative review techniques (Torraco, 2005; Petticrew & Roberts, 2006). Given the large volume of publications initially identified, filters were applied to narrow down the relevant areas and document types. Publications were initially selected based on their titles, abstracts, and keywords for more detailed review.

During the full reading of these papers, references and citations potentially relevant to this research were noted. This led to the adoption of a snowballing approach (Wohlin, 2014), utilizing the reference lists of papers to identify additional relevant studies. Given the interdisciplinary nature of the research terms, this strategy was crucial to avoid missing out on significant publications. A thematic analysis of the studies was then conducted to identify key themes and concepts, which formed the foundation for organizing the researched topics. Tools like a spreadsheet and Mendeley® software were employed for organizing and annotating the papers.

4.3 Model Design and Development

The third step in creating our proposed model started with identifying the key dimensions of the modeling structure for the collaborative network. We began by addressing some fundamental questions, leading to the definition of four main dimensions: domain, actors, objectives, and collaborative processes.

These dimensions were essential in characterizing the components within the realm of tourism management at Brazil's cultural and natural WHS, aligning with the first specific goal of the thesis. For the structure of the collaborative network model, we utilized the concept of a metamodel, employing the Unified Modeling Language (UML) notation. The choice of UML was influenced by studies demonstrating its effectiveness in representing metamodels, particularly class diagrams (Benaben

et al., 2020; Semar-Bitah & Boukhalfa, 2019; Venero et al., 2019). Lucidchart®, a web-based diagramming software tool, was used to create the artifacts.

The next phase involved specifying an architectural model for the collaborative digital platform. A range of platform requirements was raised from existing literature, which encompassed strategy, architecture, and governance at three conceptual specification levels. The digital platform architecture model prepared by Zutshi and Grilo (2019) was used, notable for its conceptual architecture of five technological layers. Each layer comprises subsets of logical components, facilitating the automation of operations within the collaborative network.

4.4 Checking the Structure with Experts

This stage of the Design Science Research Methodology (DSRM) involved evaluating the structure of the proposed model with experts, using a questionnaire composed of dichotomous and objective questions. The aim of these questions was to minimize influence on the respondents and to gather insightful feedback for improving the designed artifact. As Verschuren and Hartog (2005) suggest, this phase focuses on assessing the rigor and relevance of the designed artifact. It follows the principles of design science research, ensuring that the artifact's characteristics, aspects, and components align with the research problem's requirements and assumptions.

Given the project's focus on technological development and the collaborative network model supported by a digital platform, which encompasses various technological aspects, models, and systems, the evaluation was limited to specialists in this area. The questionnaire was not distributed to professionals in the fields of tourism and World Heritage, although involving them is proposed for future research.

The overall goal of the Framework Method is to identify, describe, and interpret the key patterns within and across cases of a theme in a phenomenon of interest. It is most commonly used for thematic analysis of semi-structured interview transcripts, although it is adaptable for other types of textual data (Gale et al., 2013). In this research the method was used to analyze the selected documents and studies. The verification of the structure with 12 Brazilian experts (11 experts have a PhD). Nine experts have some connection with the area of Information Technology and other three areas such as Production Engineering, Engineering and Mathematics.

The experts answered eleven semi-structured questions in the period from August 3rd until 22nd. The Q1 refers to the modeling structure and the description of all concepts and relationships in the collaborative network. The Q2, Q3 and Q4 deal the representation of the main dimensions or elements of this structure. Q5 to Q10 were created to evaluate each individual layer of the digital platform architecture model. The Q11 evaluates the complete model designed, considering a digital platform architecture model consisting of a business layer and five technological layers that support the requirements of a collaborative network model.

5. Results

This study argues that an inter-organizational collaborative network can be configured, based on the principles of Tourism 4.0, to constitute a model for integrated management of tourism activities of a WH and development of a self-sustaining heritage destination. In Figure 1, a collaborative network architecture model supported by a digital platform and knowledge engineering is illustrated.

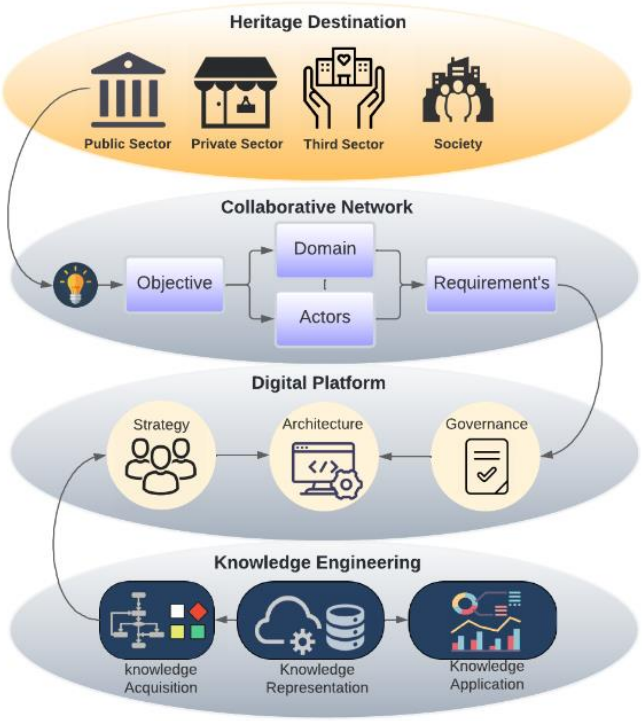

Fig.1. Collaborative network architecture model

5.1 Elements of the Collaborative Network Model

The goal-setting process aimed to define productive, specific, measurable, and quantifiable objectives with a limited timeframe and associated domain metrics (Venero et al., 2019). A review of literature, including official UNESCO documents and the National Program for Cultural and Natural Tourism project, identified 14 common strategic objectives for a collaborative network managing tourism at cultural and natural WHS in Brazil (Table 2).

Table 2. Common objectives for the composition of a collaborative network

Objective	Details	Reference
1	Official Recognition of Cultural and Natural Assets: Focuses on valuing the ten EUV evaluation criteria and raising awareness among tourism stakeholders, including the local community and public managers, about the responsibilities associated with WHS status	Gao et al. (2019); Landorf (2009); UNESCO (2019)
2	Legal and regulatory framework for tourism: ensures access to legislation governing the balance between conservation and sustainable tourism in WHS municipalities, covering the responsibilities of all government levels and civil society	Akbar et al. (2019); Kangkhao (2020); UNESCO (2019)
3	Authenticity and Integrity of Cultural and Natural Property: involves understanding by public agents of the information sources attesting to the values and authenticity of cultural property, and the integrity conditions of natural property	Bashir and Sawhney (2021); Chong and Balsingam (2019); Gholitabar et al. (2018); Milan (2019); UNESCO (2019)
4 and 5	Cultural and Natural Heritage Management Plans: Address various issues such as equitable stakeholder participation and integrated planning for a bottom-up approach, focusing on collective responsibility and effective communication.	Milan (2019); Harris et al. (2019); Kankghao (2020); Bushell and Bricker (2017); Chong and Balasingam (2019); Snis et al. (2021); UNESCO (2019)

	They also include urban and rural development master plans, considering the impacts of tourism and mapping land use conflicts	
6	Public-Private Financing for Heritage Conservation: seels funding mechanisms for conservation activities of the WHS, including a national fund, public-private, partnerships, pricing policies, and other strategies	Bashir and Sawhney (2021); Hawkins (2004); UFSC (2020); UNESCO (2019)
7	Heritage Tourism Product and Visitor Services: aims to add new meanings to WHS, attract private investment, develop products based on WHS characteristics, identify service providers, and create cultural routes	Bogacz-Wojatanowska et al. (2019); Cassel and Pashkevich (2014); Chong and Balasingam (2019); Genovese (2016); Ishwaran and Reddy (2019); Opacic (2019); Sánchez-Martín et al. (2020), Severo (2017); Ribaudo and Figini (2017)
8	Strategic Marketing of WHS and Heritage Destinations: focuses on developing WHS branding, attracting tourist, marketing and promoting destinations, including digital technologies and social media	Kangkhao (2020); Adie and Amore (2020); Cassel and Pashkevich (2014); Márquez-Gonzáles and Herrero (2017); Surugiu and Surugiu (2015); Pierdicca et al. (2019); Clini et al. (2020)
9	Local Community Awareness and Education: empowers residents regarding WHS importance, protection, conservation, tourism opportunities and disseminates sustainable tourism practices	Kangkhao (2020); Milan (2019); Chong and Balasingam (2019); Hawkins (2004); UNESCO (2019)
10	Environmental Management and Certification Program: recognizes best practice in protection and conservation of WHS and implements international sustainable tourism standards	Bushell and Bricker (2017); Buckley (2018); Hankins (2004); UFSC (2020)
11	Monitoring and Evaluation for Tourism Activities: provides reliable data for decision-making, monitors tourism productivity goals and reports on heritage site conservation status	Ishwaran and Reddy (2019); Hawkins (2004); UNESCO (2019)
12, 13 and 14	Tourist Signage in Heritage Sites and Destinations: this involves clear and informative signage in heritage areas to guide visitors efficiently	

These objectives are fundamental to the successful management of WHS and the sustainable, self-sufficient operation of tourist destinations, including aspects like transportation and mobility to these sites (Jimura, 2016; Sánchez-Martín et al., 2020; Szymanska et al., 2021; UFSC, 2020). An exemplary model in this context is the Spanish GCPHE network, which has developed good practices in these areas. Its approach includes disseminating results and making materials accessible to the public via the network's web portal.

5.2 Modeling Structure for the Collaborative Network

The structure of the collaborative network model is designed to map out various components. It includes the characteristics of the environment, the different resources and knowledge held by the actors, shared objectives of the collaboration, and the specifics of collaborative business processes. These processes are detailed into a range of activities and also include criteria for assessing the overall performance of the collaboration.

The modeling framework reuses concepts from reference (meta)models found in literature (Bidoux et al., 2014; Ermilova & Afsarmanesh, 2008; Semar-Bitah & Boukhalfa, 2016), particularly drawing on elements from the meta-model by Benaben et al. (2017). Additionally, it integrates concepts from the Knowledge-Intensive Process Ontology (KIPO), as defined by Santos França et al. (2015), as well as concepts from Venero et al. (2019).

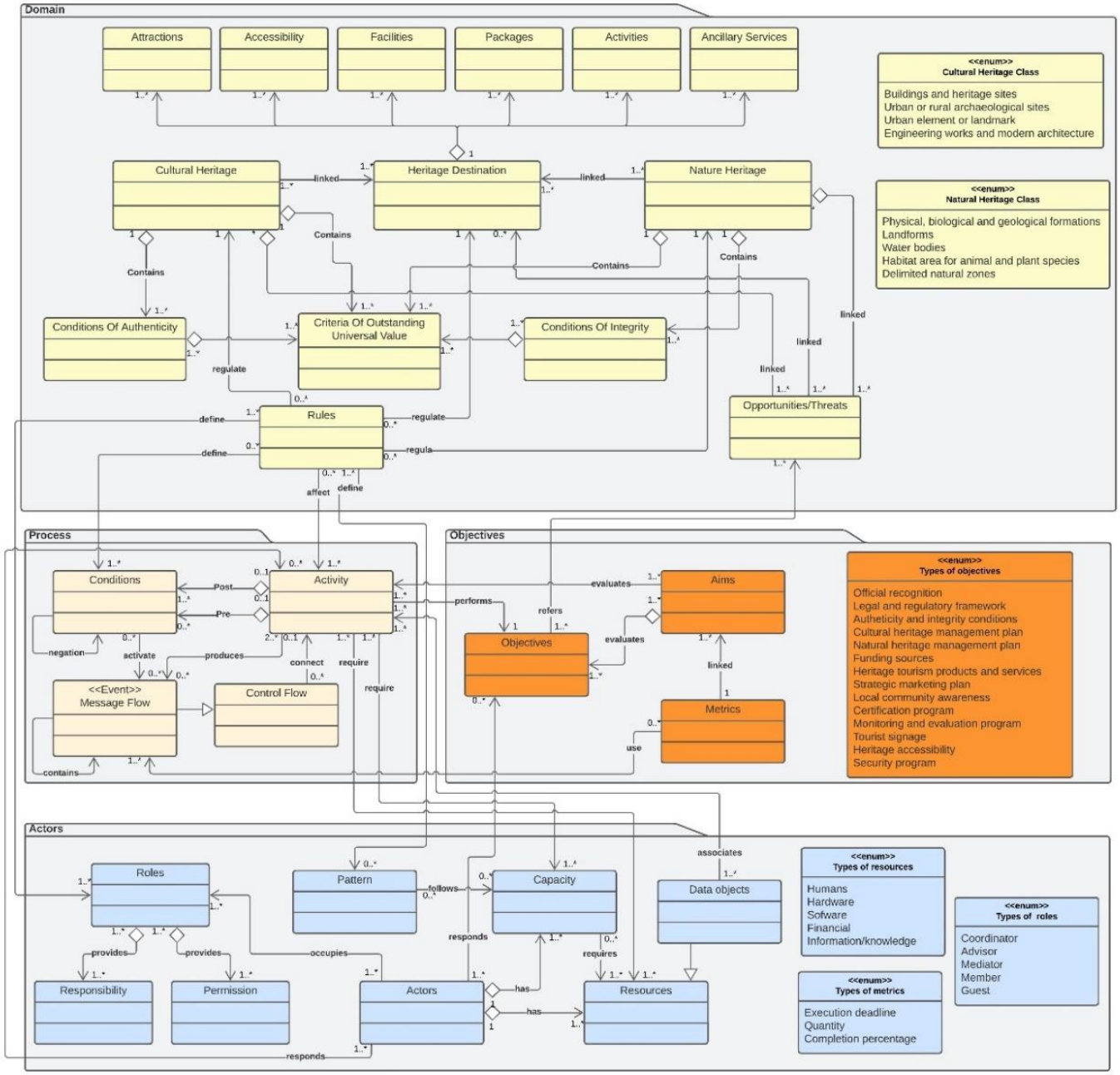

Fig. 2. Modeling framework for collaborative network in the field of tourism management in WHS

Both these sources contribute ideas and relationships to represent the knowledge in knowledge-intensive processes, especially from the angles of decision-making and collaboration.
The objectives serve as a practical means for organizations and stakeholders to maximize opportunities and address management challenges by developing joint strategic actions in this field. These objectives are assessed through specific targets, establishing a performance goal based on a type of metric. A metric is a measurable indicator of a performance goal. It is used to monitor and assess progress towards a shared aim, such as key time and effort indicators for completion. Metrics typically utilize the flow of messages or events to keep track of the collaborative process activities (Benaben et al., 2017; Venero et al., 2019).

In this research, inter-organizational business processes are interpreted as collaborative processes, governed by rules that guide the progression of activities (Santos França et al., 2015; Semar-Bitah & Boukhalfa, 2016; Grefen & Turetken, 2020). These rules align with domain regulations and can influence the execution of an activity. They may include role limitations, responsibilities, and permissions for participants, and may also mandate standards based on legal compliance and established best practices (Benaben et al., 2017; Venero et al., 2019).

At a higher level of abstraction, collaborative processes are described as a series of interconnected (macro)activities. These may be linked by a single control flow or none, often associated with each other through message flows (Santos França et al., 2015; Semar-Bitah & Boukhalfa, 2016). To achieve these shared objectives, a collaborative process must be initiated. This involves breaking down each objective into specific activities, which members of the collaborative network will address in a cooperative and coordinated way. For all objectives, four activities are proposed, which can be undertaken sequentially or concurrently, based on the required conditions.

Key prerequisites for these objectives include “assessing the current situation” of WHS, “analyzing existing norms and regulations,” and “establishing principles of homogenization.” A critical follow-up step is reaching a global consensus through an “agreed plan.” Each of these activities requires a defined control flow that outlines their inputs and outputs. They can be divided into various tasks and are likely to generate multiple communication “events.” These events, primarily “message-

based," can alter, initiate, or interrupt the activities and include logging records during their execution.

5.3 Digital Platform Architecture Model

The setup of the collaborative network requires automated support to minimize costs and maximize benefits. Therefore, this stage focuses on developing a platform architecture to sustain this ecosystem. The starting point is the work of Tura, Kutvonen, and Ritala (2018), who surveyed literature to identify key challenges and components for representing the platform's overall structure.

Defining the roles of actors on the platform is crucial for governance and value creation. This segmentation determines their responsibility, participation, and level of collaboration within the platform (Aulkemeier et al., 2019; Fürstenau et al., 2019; Tura et al., 2018). This role allocation stems from the policy structure of the collaborative network ecosystem and should encompass the roles of owner, administrator, and technical support for the platform.

Platform governance involves a set of activities that establish rules, policies, and practices for platform users, influencing decision-making and interactions. In this paper, a federated hybrid governance model is deemed most appropriate. This model allows a central authority to delegate certain responsibilities to a decentralized community of member organizations, who make independent decisions within a set framework (Gansen et al., 2018).

This digital platform architecture model incorporates main value propositions (highlighted in yellow) based on the analysis of various international networks engaged in tourism management of Cultural and Natural WHS (e.g., GCPHE, REDIPAC, SANPARKS). These value propositions represent the vision and goals for the platform's mission, articulated in the business layer and operationalized through five technology layers. Table 3 provides a conceptual mapping of the logical components of the proposed model.

Table 3. Overview of the mapping of the logical components of the platform's architecture model

Components	Details	Reference
Identity management	This subsystem registers entities (individuals or organizations) for platform access. It includes identification and authentication mechanisms, such as passwords, biometrics, and multi-factor authentication. This process involves recognizing actors and assigning them specific roles and responsibilities on the platform.	Zutshi et al. (2021); Ardakani et al. (2019); Romero and Molina (2010).
Profile and skills management	This subsystem handles the creation and maintenance of registered members' profiles, focusing on individual skills, expertise, and competencies. It defines an entity's competence as a blend of capabilities and resources necessary for tasks or activities. An ontology is required for a common understanding of these concepts.	Ardakani et al. (2019); Ermilova and Afsarmanesh (2008); Romero and Molina (2010)
Management of groups or committees	This subsystem manages information related to working groups or committees involved in various areas, including education, culture, tourism, and heritage.	Grupo Ciudades Patrimonio de la Humanidad de España – GCPHE.
Information management of the collaborative network	This subsystem manages the collaborative network's profile information on the platform. It handles general identification data such as the creation date, name, description, specific sector (domain elements), list of actors, their roles, governance rules, and more. It also requires an ontology for a unified understanding of these concepts.	Ardakani et al. (2019); Benaben et al. (2017); Romero and Molina (2010).
Collaboration Objectives Management	This subsystem characterizes proposed objectives or collaboration opportunities using a standard model. It involves formulating a basic plan for the collaborative network, orchestrating ownership, capabilities, and resources, identifying the planning and decision-making structure (top-down, bottom-up), among other configurations. Ontology-based domain knowledge structures support information provision and reasoning routines.	Ardakani et al. (2019); Grefen and Turetken (2020); Romero and Molina (2010)
Management of operational rules and policies	This subsystem establishes and maintains platform governance. It manages operational rules and bylaws for collaboration, including ethics codes, membership and leadership bylaws, roles and responsibilities, incentive policies, sanctions, and decision-making support.	Ardakani et al. (2019); Romero and Molina (2010)

The governance of the collaborative network within the platform's architecture is overseen by the subsystem dedicated to managing operational rules and policies. This subsystem is responsible for establishing a range of statutory requirements and principles. These guidelines are essential for ensuring smooth operation, security, building trust, and facilitating decision-making within the collaborative network. They also encompass defining clear objectives and setting performance metrics for evaluation.

5.4 Knowledge Engineering on the Digital Platform

Knowledge Engineering (KE) in this context is divided into two main aspects. The first is the application of modeling principles to represent knowledge within the collaborative network for tourism management at cultural and natural WHS. Here, a metamodel approach is utilized, incorporating the UML (Unified Modeling Language) notation. A metamodel, in Conceptual Engineering (CE), acts as a high-level abstraction for an ontology. It is a means to describe abstract concepts and their relationships for instantiation (Semar-Bitah & Boukhalfa, 2016, 2019; Bidoux et al., 2014; Benaben et al., 2020).

Metamodeling is particularly valuable as it allows for the use of transformation languages like the Atlas Transformation Language (ATL). This language formalizes rules to transform elements from a source language into a target language. For instance, a UML metamodel can be transformed into Semantic Web languages (OWL or RDF) or into BMPN process models, and vice versa. This transformation is facilitated by tools such as the Eclipse Modeling Framework (EMF) (Hillairet, 2007; Semar-Bitah & Boukhalfa, 2019).

The second aspect involves identifying CE tools and techniques to support knowledge management (KM) practices within the collaborative network on the digital platform. It is crucial to establish an information governance strategy across the platform from the outset. This ensures compliance, breaks down information silos, facilitates knowledge sharing, and preserves essential documents and organizational knowledge digitally (Schubert & Williams, 2022).

Knowledge storage mechanisms tied to the platform's data services are underpinned by a virtualization strategy. This meets the requirements for data search, retrieval, analysis, and visualization. Tools developed with natural language processing, machine learning algorithms, and deep learning, such as dashboards and business intelligence, aid in decision-making and knowledge discovery (Benaben et al., 2020).

They also contribute to a vision of smart tourism (Boes, Buhalis & Inversini, 2016), accommodating the needs and preferences of different user groups through various views and layout types (Faber et al., 2018). Lastly, the collaborative digital platform can be developed following an open and connected data policy. It can integrate data and information from various Brazilian cities using APIs, automatically collect data from web portals, networks, and social media, and standardize data formats.

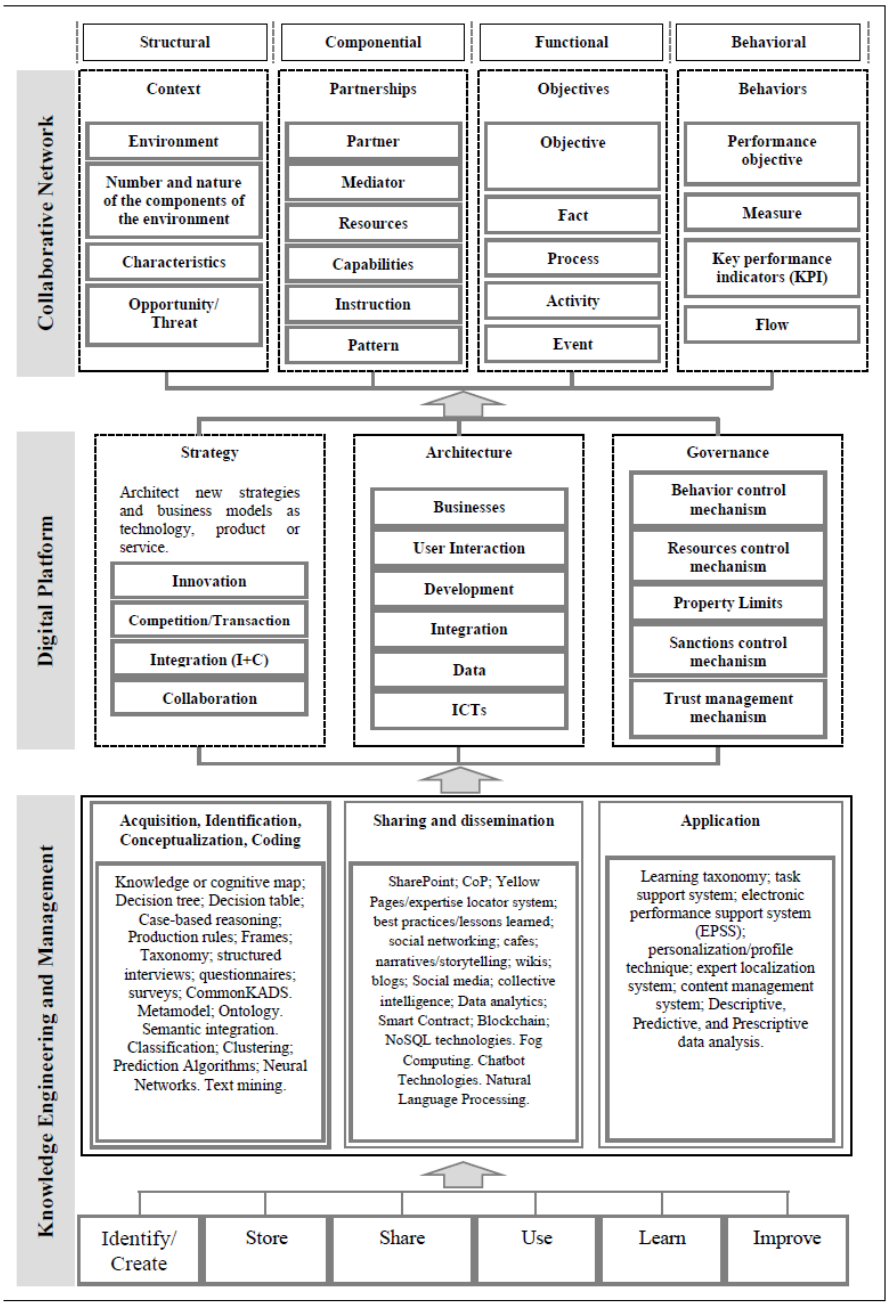

Fig. 3. Framework collaborative network architecture model supported by knowledge engineering

The collaborative platform consists of a strategy that corresponds to the orchestration of the multilateral value propositions of the collaborative relationships, the architecture that corresponds to the technological base with the possible creation or use of Application Programming Interfaces for the insertion of modules that add the functionalities and digital services of platform. The platform is formed by several layers, such as user interaction, development, integration, data, and ICT infrastructure (Zutshi & Grilo, 2019).

6. Conclusions

The composition of the collaborative network structure should combine horizontal and vertical collaboration of the actors involved, through the integration of skills, knowledge, and activities in the planning, execution, monitoring, and evaluation of common strategic objectives. The strategic goal-oriented collaborative network model should be supported by a digital platform that provides a technological environment that adds digital platform functionalities and services.

The advantage of a collaborative network management model supported by a digital platform lies precisely in the possibility of achieving an ecosystem level for knowledge creation and sharing of many-to-many collaborative relationships. The designed model followed a layer-based modular digital platform conceptual architecture approach. This architecture consists of a business layer supported by five technological layers called: User Interaction, Integration, Development, Data and ICT Infrastructure.

The logical components of platform introduce essential service subsystems to the technology layers to support the

creation and operation of the collaborative network, as well as supporting the value propositions of the platform's business layer. Knowledge Engineering techniques and tools should be integrated into the digital platform to support stakeholder interactions, enabling knowledge discovery and sharing in the collaborative network.

Knowledge Engineering was considered in two key aspects in the model design, the first in the modeling approach to represent the knowledge of the collaborative network using the metamodel concept, and the second in the identification of a set of tools and techniques to support the collaborative network in its operations within the digital platform.

From the perspective of Knowledge Engineering, the possibility of capturing, coding, processing, and extracting knowledge from data and information about tourist activities in cultural and natural PM sites and heritage destinations with the use of advanced techniques of artificial intelligence and science data is another practical contribution of this thesis. The modular characteristic facilitates the integration, through APIs, of solutions that add value to the digital platform, providing the advantage of starting with basic services and expanding as the need increases.

As a limitation, the research presents biases in the interpretation of experts' suggestions when verifying the model structure. The chosen set of experts did not make it possible to capture the perspective of knowledgeable parties in the domain, but only from a technological point of view, and in addition to this, the limited number of respondents. The lack of implementation of the model in the form of a prototype is another limitation.

Future work can: i) investigate and evaluate new collaborative business models supported by a digital platform considering the possibilities and new organizational structures offered by advanced technologies, ii) The development of a project that can be explored at the macro level of the country, at the micro level of the region or at the meso-organizational level. Therefore, some pilot project should be carried out, including tourism companies and tourism service providers, finding ways for the local community to participate through the adoption and integration of a variety of new tourism 4.0 technologies.

Declaration of competing interests

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