IONIAN UNIVERSITY

FACULTY OF INFORMATION SCIENCE & INFORMATICS

DEPARTMENT OF ARCHIVES, LIBRARY SCIENCE

AND MUSEOLOGY

Master of Science in

«Digital Information Management - Information Services»

MASTER'S THESIS

«Knowledge Representation and Modelling of Elements of Vernacular Architecture»

Tsiouprou Katerina

Corfu March, 2026

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Acknowledgements / Dedication

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Abstract

The documentation of cultural heritage has become an important topic in the fields of digital libraries, computing, and information studies. Architecture is a major part of cultural heritage because it reflects the history, values, and way of life of human societies. In particular, vernacular architecture is important because it represents local building traditions that developed over time in response to social needs, environmental conditions, available materials, and cultural practices. Although vernacular architecture is an essential part of cultural heritage, its documentation is often limited and lacks a clear semantic structure. This master thesis proposes a data model for documenting vernacular architecture based on CIDOC CRM, a well-known conceptual reference model used for the representation and integration of cultural heritage information. The aim of the thesis is to show how CIDOC CRM can support the structured documentation of vernacular architecture and help describe its cultural, historical, and architectural dimensions in a consistent way.

The thesis begins by examining the concept of vernacular architecture and reviewing previous work on the documentation of architecture in cultural heritage and information systems. It then develops a CIDOC CRM-based model that captures the main aspects of vernacular architectural knowledge. More specifically, the model represents the contexts in which vernacular architecture is created, including environmental, social, and historical factors. It also describes important architectural features, such as construction techniques, building materials, morphological characteristics, and typological patterns that define vernacular forms.

In addition, the proposed model documents the relationships between different vernacular architectural traditions. These relationships include temporal succession, stylistic influence, and cultural interaction. In this way, the model does not treat vernacular buildings as isolated objects, but as part of broader cultural processes and traditions. To demonstrate the usefulness of the model, the thesis presents two case studies: The Igloo and the Mongolian Yurt. These examples show how the CIDOC CRM can be used to represent different types of vernacular architecture from different cultural and geographical contexts.

Keywords

Vernacular Architecture, CIDOC CRM, Ontologies, Data Model, Cultural Heritage Documentation, Intangible Cultural Heritage (ICH).

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Title and Abstract of the Thesis in Greek

«Αναπαράσταση Γνώσης και Μοντελοποίηση Στοιχείων της Λαϊκής Αρχιτεκτονικής»

Περίληψη

Η τεκμηρίωση της πολιτιστικής κληρονομιάς έχει αναδειχθεί σε σημαντικό αντικείμενο μελέτης στους τομείς των ψηφιακών βιβλιοθηκών, της επιστήμης των υπολογιστών και της επιστήμης της πληροφορίας. Η αρχιτεκτονική συνιστά θεμελιώδη έκφανση της πολιτιστικής κληρονομιάς, καθώς αντανακλά την ιστορία, τις αξίες και τον τρόπο ζωής των ανθρώπινων κοινωνιών. Ιδιαίτερη σημασία παρουσιάζει η λαϊκή αρχιτεκτονική, δεδομένου ότι αποτυπώνει τοπικές οικοδομικές παραδόσεις, οι οποίες διαμορφώθηκαν διαχρονικά ως απόκριση στις κοινωνικές ανάγκες, στις περιβαλλοντικές συνθήκες, στα διαθέσιμα υλικά και στις πολιτισμικές πρακτικές. Παρά το γεγονός ότι η λαϊκή αρχιτεκτονική αποτελεί ουσιώδες στοιχείο της πολιτιστικής κληρονομιάς, η τεκμηρίωσή της παραμένει συχνά περιορισμένη και στερείται σαφούς σημασιολογικής οργάνωσης. Η παρούσα μεταπτυχιακή διπλωματική εργασία προτείνει ένα μοντέλο δεδομένων για την τεκμηρίωση της λαϊκής αρχιτεκτονικής, βασισμένο στο CIDOC CRM, ένα ευρέως αναγνωρισμένο εννοιολογικό πρότυπο αναφοράς που χρησιμοποιείται για την αναπαράσταση και την ενοποίηση πληροφοριών πολιτιστικής κληρονομιάς. Στόχος της εργασίας είναι να αναδείξει τον τρόπο με τον οποίο το CIDOC CRM δύναται να υποστηρίξει τη δομημένη τεκμηρίωση της λαϊκής αρχιτεκτονικής και να συμβάλει στη συνεπή περιγραφή των πολιτισμικών, ιστορικών και αρχιτεκτονικών της διαστάσεων.

Η εργασία εκκινεί με την εξέταση της έννοιας της λαϊκής αρχιτεκτονικής και την επισκόπηση προγενέστερων προσεγγίσεων σχετικά με την τεκμηρίωση της αρχιτεκτονικής στο πλαίσιο της πολιτιστικής κληρονομιάς και των πληροφοριακών συστημάτων. Στη συνέχεια, αναπτύσσεται ένα μοντέλο βασισμένο στο CIDOC CRM, το οποίο αποτυπώνει τις κύριες πτυχές της γνώσης που σχετίζεται με τη λαϊκή αρχιτεκτονική. Ειδικότερα, το μοντέλο αναπαριστά τα συμφραζόμενα εντός των οποίων δημιουργείται η λαϊκή αρχιτεκτονική, συμπεριλαμβανομένων περιβαλλοντικών, κοινωνικών και ιστορικών παραγόντων. Παράλληλα, περιγράφει σημαντικά αρχιτεκτονικά χαρακτηριστικά, όπως οι τεχνικές κατασκευής, τα δομικά υλικά, τα μορφολογικά γνωρίσματα και τα τυπολογικά πρότυπα που συγκροτούν τις λαϊκές αρχιτεκτονικές μορφές.

Επιπροσθέτως, το προτεινόμενο μοντέλο τεκμηριώνει τις σχέσεις μεταξύ διαφορετικών παραδόσεων λαϊκής αρχιτεκτονικής. Οι σχέσεις αυτές περιλαμβάνουν τη χρονική διαδοχή, τη στιλιστική επιρροή και την πολιτισμική αλληλεπίδραση. Με τον τρόπο αυτό, το μοντέλο δεν αντιμετωπίζει τα λαϊκά κτίσματα ως απομονωμένα αντικείμενα, αλλά ως τμήματα ευρύτερων πολιτισμικών διεργασιών και παραδόσεων. Προκειμένου να καταδειχθεί η χρησιμότητα του μοντέλου, η εργασία παρουσιάζει δύο μελέτες περίπτωσης: το Ιγκλού και τη Μογγολική Γιούρτα. Τα παραδείγματα αυτά αναδεικνύουν τον τρόπο με τον οποίο το CIDOC CRM μπορεί να αξιοποιηθεί για την αναπαράσταση διαφορετικών τύπων λαϊκής αρχιτεκτονικής, προερχόμενων από διαφορετικά πολιτισμικά και γεωγραφικά συμφραζόμενα.

Λέξεις Κλειδιά

Παραδοσιακή (Λαϊκή) Αρχιτεκτονική, CIDOC CRM (Εννοιολογικό Μοντέλο Αναφοράς), Οντολογίες, Μοντέλο Δεδομένων, Τεκμηρίωση Πολιτιστικής Κληρονομιάς, Άυλη Πολιτιστική Κληρονομιά (ΑΠΚ).

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Chapter 1 Introduction

Architecture is a way of expressing ideas and feelings through buildings. Scientists, philosophers and poets have been inspired by architecture and tried to describe it in their own way. Some of them called it “frozen music” or “human triumph over gravitation and the will to power”, while the professionals in the field – the architects – described it in the terms of “the will of an epoch translated into space” and “inhabited sculpture”. The shape, materials, light, space, and design of a structure can change how people feel in it. Architecture can reflect culture and history, with symbols like arches or domes, and blend with its surroundings, showing respect for nature or city life. In short, architecture can create spaces that reflect who people are and how they feel.

Throughout history, numerous architectural styles—including Greek, Roman, Gothic, Baroque, Neoclassical, Victorian, Modern, and Postmodern—have shaped the built environment. However, architectural styles go beyond visual and structural features [AKGP22]. They are influenced by aesthetics, functionality, sustainability, geography, climate, available materials, ideologies, religions, and social values. Useful in specifying structures in historical and design contexts, architectural styles have visual identities as well as classification systems. Each architectural style is outlined by particular structural and decorative features that make it stand out. Over time, styles have evolved by adding new features that reflect cultural influences and societal changes, making them historical records of human civilization and art at the same time.

Although there is an architectural style that goes beyond common structural boundaries and focuses more on the surrounding environment, from which it gains its inspiration and materials. In this thesis, we are going to describe and analyze this unique style named “Vernacular Architecture”. It is often defined as "architecture without architects" [Rud64] and it’s primarily designed to meet the practical needs of its users. These buildings were constructed using locally available materials and traditional techniques suited to the climate and environment. Examples include cottages, barns, and farmhouses that were built to support agricultural activities and daily living. Different regions developed distinct architectural styles based on climate, resources, and traditions. These buildings carry elements of cultural heritage and social practices unique to their location.

Unlike traditional architecture, which often stays the same over time, vernacular architecture is constantly evolving. It adapts to new influences, materials, and technological advancements, making it more dynamic. While traditional architecture is typically seen as a reflection of the past, vernacular architecture stays deeply rooted in its culture while adapting to changing conditions. The understanding of local culture has changed, as globalization and evolving worldwide links both physical and virtual now shape how spaces are perceived. Although globalization has led to the standardization of some architectural styles across regions, vernacular architecture remains unique. It still reflects the specific environment, culture, and needs of each place.

This adaptability of vernacular architecture highlights the need to approach it not only as a category of built form, but as a dynamic cultural process grounded in intangible knowledge systems. Far from being understood as a fixed and immutable representation of the past, vernacular architecture is sustained through the ongoing transmission and reconfiguration of culturally embedded practices and knowledge [Sal18]. This way of understanding vernacular architecture is consistent with current scholarly approaches to intangible cultural heritage, which emphasize living practices, community participation, and ongoing cultural reproduction. This process-oriented character fits well with current views of intangible cultural heritage, which focus on living traditions shaped by everyday practice, active community involvement, and the continued passing on of cultural knowledge over time.

Within the conditions of globalization and increasingly interconnected physical and digital environments, vernacular architecture provides a critical lens through which the persistence of locally embedded knowledge can be examined. While global forces may promote architectural homogenization, vernacular environments continue to express place-specific relationships between local culture, the environment, and everyday practices. Framing vernacular architecture through the lens of intangible cultural heritage shifts attention from buildings as objects to the cultural processes that shape and sustain them, providing the conceptual basis for the theoretical framework presented in the remainder of this study.

1.1 Vernacular Architecture's Definition

Studying the history of vernacular architecture often involves archaeology, especially when there are few written records. Shelters made of stone, tend to leave behind visible remains, while structures made from organic materials such as wattle, mud, or woven matting often decay without a trace. Archaeology offers important insights into early vernacular homes, but its interpretations can be uncertain since estimating past occupants or a building's lifespan is difficult [Dye97]. Historians support this approach by studying documents and physical evidence, helping to reconstruct past architectural traditions within historical contexts. Even when written records are lacking, material artifacts—including pottery, tools, weapons, textiles, and architectural ruins—offer glimpses into early human settlements [Oli06].

There is difficulty in defining exactly what vernacular architecture means as a specific architectural style. Taking a closer look, it refers to buildings constructed without the use of formal scientific principles and professional architectural guidance, and most often without the use of machinery [Zam25]. Reversely, these structures arise from the collective knowledge of local communities, using traditional materials and construction techniques that have been passed down through generations [ST21]. This allows vernacular buildings to directly express the social, cultural, natural, and economic reality of the region in which they are found. By focusing on utility, flexibility, and sustainability, vernacular architecture ensures that buildings fit their environment and meet the needs of the people who live in them.

In the mid-20th century, the definition of vernacular architecture expanded to include cultural and social influences beyond construction techniques. This led to the view that vernacular architecture was concerned with function, emphasizing instead a deep connection to human values, traditions, and ways of life [BM12]. In the past, these buildings were often associated with national identity, reinforcing the uniqueness of a culture. Governments have even used vernacular architecture as a political tool, either to preserve heritage or to promote nationalist ideals, since in the past vernacular architecture buildings differentiated cultures by emphasizing the uniqueness of each [Oli06].

Unlike academic or formal architecture, which often complies with strict design theories and global trends, vernacular architecture is rooted in empirical knowledge, cultural traditions, and sensitivity to local conditions. It evolves over time through a process of collective experimentation and refinement, resulting in structures that are highly adapted to their environments and socio-cultural contexts [Fue23]. Without having specific aesthetic and design principles like Gothic, Baroque, or Modernism style, vernacular architecture is better understood as an approach rather than a fixed style. It is also part of traditional architecture, which includes a wide range of techniques and practices passed down through generations, helping preserve cultural identity while allowing for change. Firmly grounded in cultural and contextual foundations, this style reflects customs, and the way of life of the people who create and inhabit these spaces. Vernacular Traditional buildings are characterized by uniqueness. This arises by considering their diverse location, the climate and geography of the area, the materials available in the surrounding area, as well as the cultural values that their respective locals attribute to them [LC24]. This approach ensures that vernacular architecture remains a dynamic and evolving building form, capable of adapting to new influences, while preserving its strong ties to its cultural and environmental context.

Because of the use of traditional materials from its specific geographic location, these buildings reflect the lifestyle, social organization, family structures, and cultural identity of the residents. They are more than just shelters; they serve as expressions of a community's way of life, incorporating symbolic and practical elements that harmonize with local customs and beliefs. For instance, the design of a house may reflect religious or spiritual principles, such as the orientation of a building based on cultural or religious preferences or the inclusion of communal spaces that encourage social interactions.

Vernacular architecture plays a crucial role in helping historians reconstruct the past, as these buildings stand as physical records of how people lived, worked, and interacted with their environment. Historically, it has been referred to as "the architectural language of the people", shaped by the use of local materials, climate conditions, and social customs [Rud64].

1.2 Attributes of Vernacular Architecture

Vernacular architecture is defined by several key characteristics with tradition and context being its two core elements. These factors shape the uniqueness of vernacular buildings, showing the origins and traditions of their ethnic or regional groups. Tradition is an essential part of vernacular architecture because these buildings are made using techniques and knowledge passed down through generations, as well as locally sourced materials - such as mud, stone, wood, bamboo, or even snow (as seen in igloos). This type of architecture is fundamentally practical, planned to meet the basic needs of shelter for people, animals, and storage. It is shaped by the availability and performance of materials, as well as by environmental and climatic conditions [Als14]. Context, on the other hand, determines how these buildings relate to their surroundings by taking into account factors like climate, landscape, available materials, and cultural practices. This close relationship to the environment makes vernacular architecture both functional and sustainable, as it naturally incorporates eco-friendly practices like natural ventilation, thermal mass, and passive solar heating. With its capability to adapt and evolve through time, making it possible to have a physical interaction with the local climate and the geography of a place, for example, thick adobe walls regulate heat in desert environments, while stilt houses protect against flooding in water-prone regions. Under these circumstances, vernacular architecture remains functional, resilient, and deeply connected to the communities it serves [ATK+25].

Another essential feature is cultural relevance, as vernacular architecture embodies the social values, traditions, and daily practices of the communities that create and inhabit it. It serves not only to meet physical needs but also to reflect cultural identity and ways of life. The completed shape of a vernacular architectural settlement is often influenced by social, cultural, economic, defensive, and religious factors. Even resource accessibility and construction techniques can affect their final form. For example, in areas where timber is difficult to find, stone, clay or mud may be used. Another factor that can shape the layout of dwellings is the defensive needs, resulting in fortified villages or raised houses in flood-affected regions. In addition, religious beliefs and social hierarchies are considered when deciding the size and placement of buildings, making sure they reflect community values and spiritual traditions [Özk95]. Many traditional structures use passive climate control methods, such as natural ventilation and solar orientation, making them inherently sustainable. Their construction techniques often use environmentally friendly, locally sourced materials, emphasizing efficiency and innovation.

In this assignment, fourteen (14) specific characteristics were set so that a model of vernacular architectural elements could be attributed. These attributes will function as basic parameters in the structuring of the model.

No.	Attributes	Documentation
1.	Appellation	The name of the structure is constructed by the type of the structure and the region or culture
2.	Place/Region	Parameters of a place or the region which is located a significant vernacular architectural structure.
3.	Microclimate	The microclimate of the area in which the building is constructed.
4.	Topography	The site and its existing conditions affect the design as they inform the appropriate use of the site.
5.	Culture	The way of life of building occupants, and the way they use their shelters, is of great influence on building forms. The size of family units, which share spaces, how food is prepared and eaten, how people interact and many other cultural considerations will affect the layout and size of dwellings.
6.	Local Traditions	Refers to the tried-and-tested construction techniques of built forms that have survived the test of time over multiple generations. Also refers to the purpose of the existence of a building. Vernacular architecture could be understood as the building traditions that have been developed by people over generations and often built by themselves.
7.	Dating	An approximate estimation is attempted. Dating a vernacular structure is a very difficult and ambiguous process. The time of creation may be strictly connected with the existence of a civilization /tradition.
8.	Materials	Traditional materials and resources from the local area, which are used to construct the buildings. Areas rich in trees will develop a

		wooden vernacular, while areas without much wood may use mud or stone.
9.	Type	The type of vernacular structure in terms of a general categorization.
10.	Technique	Description of a specific technique that is followed for a specific vernacular structure.
11.	Seasonality	A vernacular structure is also connected with a season. The same culture may have a different vernacular structure depending on the season. It is strictly connected with entity Use/Function.
12.	Use/Function	The type of structure and materials used for a dwelling vary depending on how permanent it is. Frequently moved nomadic structures will be lightweight and simple, more permanent ones will be less so. When people settle somewhere permanently, the architecture of their dwellings will change to reflect that.
13.	Religious Beliefs	Faiths as ways of life and social memory have had considerable influence on, among - other things - the shaping of the built environment.
14.	Patterns	Despite vernacular variations, every building is subject to the same laws of physics and hence will demonstrate significant similarities in structural forms.

Table 1: Characteristics of the Vernacular Architecture elements

1.3 Intangible Cultural Heritage: Definition and Characteristics

Intangible Cultural Heritage (ICH) constitutes a fundamental dimension of cultural heritage, encompassing living practices, expressions, knowledge systems, and skills that communities recognize as part of their cultural identity and continuity. Unlike tangible heritage, which is embodied in monuments, artefacts, and sites, ICH exists primarily through practice, performance, and transmission, rendering it inherently dynamic and processual [Gim04].

The international recognition of ICH as a distinct heritage category was formalized with the adoption of the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, which marked a paradigmatic shift in heritage discourse. This shift redirected attention from the conservation of material remains to the safeguarding of living cultural processes and emphasized the central role of communities as heritage bearers [Une03]. According to the 2003 Convention, Intangible Cultural Heritage comprises: "*the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage*" [Une03].

This definition foregrounds three interrelated dimensions: first, the embodied and performative nature of heritage practices; second, the recognition of heritage by communities themselves, rather than by experts alone; and third, the continuous recreation of these practices in response to changing social, historical, and environmental conditions [Kur07]. UNESCO identifies five broad domains of ICH: oral traditions and expressions, performing arts, social practices and rituals, knowledge concerning nature and the universe, and traditional craftsmanship. These domains should be understood not as rigid classificatory units but as heuristic categories that often overlap in lived cultural practice.

A defining characteristic of ICH is its living and dynamic character. Cultural practices are not preserved through fixity but through adaptation and reinterpretation across generations. As Kirshenblatt-Gimblett notes, ICH is sustained precisely through its capacity to be performed anew, rather than replicated unchanged. Equally significant is the community-based nature of ICH. Heritage value emerges through social recognition and shared meaning, challenging object-centered and expert-driven heritage paradigms [Smi06]. In this sense, ICH reconfigures heritage authority, relocating it from institutions to practicing communities. Transmission typically occurs through informal, experiential learning, such as apprenticeship, observation, and oral instruction. This mode of transmission renders ICH particularly vulnerable to social disruption, population decline, and shifts in economic structures [Har13]. Intangible Cultural Heritage plays a crucial role in shaping collective identity and social memory. Through rituals, craftsmanship, storytelling, and embodied knowledge, communities articulate shared histories, ethical values, and worldviews [Smi06]. Such practices often encode locally situated knowledge, including environmental adaptation strategies and cosmological understandings.

1.4 Vernacular Architecture within the Framework of Intangible Cultural Heritage

Vernacular architecture belongs to the domain of Intangible Cultural Heritage because its cultural significance resides not only in built forms but primarily in the knowledge systems, skills, practices, and social processes through which these structures are conceived, constructed, and maintained. While vernacular buildings may survive as tangible artefacts, they are the material outcome of embodied know-how, transmitted through apprenticeship, oral instruction, and communal practice rather than formalized architectural design [Oli97]. Construction techniques, material selection, spatial organization, and adaptive responses to climate and landscape reflect locally situated knowledge that is continuously recreated in response to environmental and social conditions, aligning closely with the UNESCO understanding of ICH as living, dynamic, and community-based heritage [Une03]. Moreover, vernacular architecture is deeply embedded in social practices, belief systems, and collective identity, functioning as a cultural process rather than a static object. From this perspective, the loss of vernacular architecture is not merely the disappearance of buildings, but the erosion of traditional craftsmanship and environmental knowledge, which are explicitly recognized as domains of Intangible Cultural Heritage [Gim04, Har13].

1.5 Documenting Intangible Cultural Heritage in Digital Environments

Safeguarding Intangible Cultural Heritage (ICH) differs fundamentally from the conservation of material heritage. The UNESCO 2003 Convention emphasizes supporting the conditions for continued practice and transmission, rather than freezing cultural expressions in fixed forms [Une03]. Safeguarding measures may include documentation, education, community-based initiatives, legal recognition, and policies that support cultural practitioners. Within this framework, documentation—whether textual, audiovisual, or digital—plays an important supportive role but must not substitute for living practice [Kur07]. Recent scholarship highlights the need for digital and conceptual environments capable of representing not only cultural outputs but also processes, actors, skills, and events of transmission. In this context, the CIDOC Conceptual Reference Model (CIDOC CRM) [Une03] provides a robust semantic framework for documenting Intangible Cultural Heritage by enabling the structured representation of cultural activities, participants, knowledge transmission, and their temporal and social relationships, thereby supporting interoperability, long-term usability, and meaningful reuse of ICH documentation in digital heritage systems.

Chapter 2 Related Work

In comparison with international styles, which are typically shaped by formal principles and global trends, vernacular architecture follows a localized, culturally embedded model of development, offering a distinctly different approach to modeling. It analyzes architectural form through elements such as building techniques, decorative features, and spatial layouts, each tied to local materials, environmental conditions, and cultural traditions. This bottom-up perspective highlights how architectural identity grows naturally from the interaction between people, their surroundings, and their customs, rather than from formal design theories [ATK+25].

In order to represent these distinctive features within a systematic framework, the principles of vernacular architecture need to be translated into a structured data model. For this purpose, this chapter discusses the tools and the pre-existing data models that were used as a basis for developing and describing the vernacular architecture data model, which will be presented in Chapter 4. A framework that plays a crucial role in this context is the CIDOC Conceptual Reference Model (CIDOC CRM). It is a knowledge representation model designed to organize, describe, and harmonize diverse cultural heritage information. CIDOC CRM is commonly accepted as one of the most suitable frameworks for modeling interrelations and establishing mappings between diverse information sources, with notable examples including mappings from metadata schemas such as EAD to CIDOC CRM [BG11], VRA to CIDOC CRM [GG12], as well as from other conceptual models like RiC-CM to CIDOC CRM [BDD+23].

It is important to mention that several CIDOC CRM-based data models have also been developed in the domain of archaeology, focusing on the documentation of excavation context sheets and archaeological structures. An instance of this is the use of CIDOC CRM and its extension CRMba [RNF+16] to represent archaeological buildings that of the Origins of Doha and Qatar Project in the village of Fuwairit, Qatar. This work supports and contributes to the documentation and management of cultural heritage information, and adds to the discussion on shared interests and efforts among digital humanities, computing and information studies [GMK+21].

Within this context, a case study engaged with architectural structures and the broader architectural framework by proposing a data model for the description of archaeological buildings using CIDOC CRM in conjunction with CRMba. The model represents a systematic approach to documenting architectural remains in archaeological sites and was applied to buildings excavated in the settlement of Fuwairit, Qatar, within the same research framework of the Origins of Doha and Qatar Project. The aim was to provide archaeologists with a tool that allows for a user-friendly, systematic, and efficient recording of excavation data [GPK+21] directly into an electronic database. The shift from traditional, handwritten documentation to a digital infrastructure not only ensures the security and preservation of information, which is no longer at risk of loss or deterioration, but also enhances accessibility, searchability, and reusability of data across multiple contexts. In this way, archaeologists acquire a versatile tool that supports study, documentation, and analysis, as well as the preparation of material for exhibitions or research presentations [GMK+21].

At the same time, the development of such a database addresses the needs of museum collection management, as it offers a reliable solution for organizing collections and handling the vast amount of information they contain. The standardized documentation resulting from this model also ensures interoperability between scholars and institutions, both nationally and internationally, facilitating the exchange and integration of knowledge concerning cultural heritage. The semantic consistency achieved through CIDOC CRM and its extensions makes the data reusable and process able, thereby strengthening research and encouraging technological innovation in the field of the humanities.

The structure of the thesis is organized into three main chapters. The first chapter provides a literature review of archaeological science and, more specifically, building archaeology, while also presenting the CIDOC CRM model and its extension CRMba, with emphasis on their field of application, structure, and specialized vocabulary. The second chapter is dedicated to the Origins of Doha and Qatar Project, which served as the case study, and includes historical information about the wider region of Fuwairit. The third chapter introduces the proposed model for the description of buildings, along with examples of its application to selected structures. In practice, the model was applied to six out of the twenty-five recorded buildings of the site, since the remaining cases did not present significant differentiations.

This selective approach aimed to develop a simple and flexible model intended to support the digital documentation of architectural remains. While the model does not place particular emphasis on decorative aspects, it focuses on the representation of structural and morphological features, offering archaeologists an initial framework for recording architectural data. In this context, the thesis situates the proposed approach within ongoing efforts to integrate archaeological research with digital documentation tools for cultural heritage [GMK+21].

A similar case is a model for documenting architectural styles via CIDOC CRM and its extensions. This paper has modelled the way that architectural styles and periods interact, forming human-built historic environments, parts of the world's cultural heritage. This piece of ongoing research adds to the documentation and management of cultural heritage information, while addresses the challenge of formally representing architectural styles within digital cultural heritage systems [AKGP22] A significant contribution of the paper lies in its conceptual clarification of what constitutes an architectural style. The authors approach the architectural style as a complex cultural dynamic which is formed by historical, social, ideological and environmental conditions rather than simply a set of morphological characteristics. This theoretical standpoint allows architectural styles to be modeled as entities with temporal depth, spatial distribution, creators, materials, techniques, and relationships to other styles, such as influences, revivals, and regional variations.

The paper gives the definition of an "architectural style" and discusses the theoretical background of the concept, while reviewing previous work on the digital documentation of architecture. In the following step, presenting a proposed model which enables the representation of the historical context and the structural and decorative elements of an architectural period and, also, the temporal and spatial relationships between architectural styles, including influences, sub-periods, regional variations, and revivals.

Methodologically, the paper introduces a series of CIDOC CRM–based data models that address different dimensions of architectural styles. These include models for representing the historical context of a style, its defining architectural elements (materials, construction techniques, decorative features, and plans), and the relationships between styles and architectural periods. The authors also demonstrate how individual buildings or building components can be linked to one or more architectural styles using the CRMba extension, which is specifically designed for documenting standing buildings and architectural remains.

As an example, the Gothic architectural style was used to demonstrate how CIDOC CRM can link architectural styles with periods, creators, places, materials, techniques, and specific buildings or building parts. This theoretical standpoint allows architectural styles to be modeled as entities with temporal depth, spatial distribution, creators, materials, techniques, and relationships to other styles, such as influences, revivals, and regional variations.

In general, the paper makes an important contribution to the field of digital heritage documentation by extending the use of CIDOC CRM beyond individual objects or excavation data to the level of architectural styles used for analysis and interpretation. It highlights the potential of ontological modeling to support interoperability, comparative analysis, and deeper scholarly interpretation, and it explicitly identifies vernacular architecture as a promising area for future research using the proposed approach.

Regarding the CIDOC CRM and its extensions, another study has explored their use to enhance semantic interoperability in archaeology, particularly in the integration of heterogeneous data sources. Notable is the development of a methodology for the automatic generation of enriched metadata from archaeological excavation reports (gray literature). This approach employs the CIDOC CRM extension for archaeology (CRM-EH) as its conceptual model core and incorporates Natural Language Processing (NLP) techniques through the GATE framework, combined with SKOS-based thesauri, to extract structured semantic annotations from unstructured textual reports.

The proposed three-phase process for semantic enrichment works by identifying meaningful entities and relationships within excavation reports and transforming them into structured XML annotations and RDF metadata. In this way, information that originally exists in free-text form becomes machine-readable and semantically connected. These structured outcomes are assembled into a single semantic framework, giving users the ability to seamlessly search both excavation databases and text reports through the STAR demonstration platform.

The evaluation of the results reveals encouraging levels of precision and recall in different modes of semantic extension (synonym, hyponym and hypernym). Taken together, the findings indicate how ontology-based semantic enrichment can effectively bridge the gap between structured archaeological datasets and unstructured textual documentation, improving access to and incorporation of archaeological knowledge [BVM+13].

Extending the combination of CIDOC CRM model and SKOS-based thesaurus in the field of archaeology, further relevant research has been conducted. Archaeological datasets commonly represent time periods through various textual and numeric expressions. Traditionally, controlled vocabularies have relied on classification notation and the collocation of terms in printed form to implicitly convey the relative chronological order of concepts. However, with the transition to the Semantic Web, this knowledge must be encoded in machine-readable formats, and the meaning embedded in informal ordering arrangements can easily be lost. Although the conversion of controlled vocabularies into the Simple Knowledge Organisation System (SKOS) provides a formal basis for semantic indexing, it does not support chronological inference, since standard thesaurus relationships are insufficient to fully describe temporal relations. This limitation becomes particularly problematic in archaeology, where periods are often defined by named monarchs or emperors without explicit chronological context.

Within the framework of the STAR (Semantic Technologies for Archaeological Resources) project, researchers worked to enrich existing time period vocabularies by adding clear dates and defined temporal relationships, based on the CIDOC CRM and OWL-Time. The author proposes modeling time periods as CIDOC CRM entities and encoding relations using some of the model properties. Once these temporal relationships are clearly defined, the approach allows reasoning across both relative and absolute chronologies and improves chronological navigation [Bin10]. This work, situated within the broader goal of STAR to demonstrate the benefits of cross-searching archaeological data structured under a common conceptual schema, contributes significantly to improving semantic interoperability in temporally structured archaeological information systems.

The results of the STAR project analyzed in a subsequent paper. Aim of this paper is to improve access to and interoperability between heterogeneous archaeological datasets and reports. The project addresses the need to widen access to archaeological data, enabling third parties to cross-search different datasets and examine the evidential basis of interpretations. To achieve this, STAR employs semantic technologies grounded in standard representations of domain vocabularies and a shared core ontology, namely CIDOC CRM and its archaeological extension, CRM-EH.

The paper describes methods for mapping diverse archaeological databases into RDF, supported by the development of a semi-automatic mapping tool. It also outlines the integration of SKOS-based thesauri through terminology web services, emphasizing the importance of controlled vocabularies for semantic consistency. In addition, Natural

Language Processing (NLP) techniques are applied to extract semantic entities from OASIS grey literature and convert them into RDF representations, allowing structured information to be derived from unstructured textual sources. The STAR demonstrator showcases unified semantic search and interconnected browsing between data instances and the conceptual model, illustrating the practical benefits of semantic technologies in enhancing interoperability and access to fragmented archaeological resources [BMS+13].

This article proposes a specialized extension of CIDOC CRM for representing megalithic monuments, responding to the documentation needs found in archaeological grey literature and official heritage registries, such as the Portuguese Archaeologists' Portal. While the concept of Megalithism is discussed in archaeological and prehistorical scholarship, as well as in general dictionaries and glossaries, formalized knowledge representations specific to this domain remain limited. The authors therefore introduce an ongoing proposal for a CIDOC CRM–based knowledge model tailored to the representation of European Megalithism.

The proposed model accounts not only for monument types (e.g., dolmens, menhirs, cromlechs) but also for their internal structure and granularity, representing composite architectural components such as chambers, corridors, and individual standing stones. It further incorporates appellations, spatial location, dimensions, and legal protection status, while acknowledging the importance of documenting uncertainty and multivocality in archaeological interpretation. By aligning the model with FAIR principles, the approach aims to create reusable, interoperable, and semantically enriched information structures, providing a structured foundation for future knowledge extraction and analysis of megalithic monument reports [SVT+22].

The paper proposes the use of CIDOC CRM and its extensions, CRMsci and CRMdig, to document the scientific experiments conducted within archaeological investigations. Recognizing that archaeometric techniques such as radiocarbon dating (C14), XRF, FTIR, and similar methods generate complex digital datasets, the author analyzes the nature of these experiments and emphasizes the need for systematic documentation of their critical components. A distinction is drawn between observations and analyses, highlighting the importance of recording the full experimental protocol, including sample selection (whether physical or "virtual"), equipment and parameter settings, environmental conditions, data post-processing, and the research purpose motivating the analysis.

To address these documentation requirements, the author introduces a new extension of CIDOC CRM, named CRMas, which builds upon CRMsci and CRMdig. This extension incorporates newly defined classes and properties—such as the concept of a Virtual Sample—to model both destructive and non-destructive sampling processes. By formally representing scientific workflows within a semantic framework, the proposed model aims to enhance transparency, support data reuse, and enable the assessment of reliability in archaeological scientific investigations.

Over the last decades, CIDOC CRM has become the internationally recognized standard for modeling cultural heritage data, and its application has progressively expanded beyond museum documentation to broader areas of the digital humanities, including the digital publication of archaeological catalogues [Dei16]. In this context, the article presents an exemplary CIDOC CRM–based model for representing archaeological catalogue data, with particular emphasis on the semantic organization of finds, burial contexts, objects, and their interrelations. Designed for implementation in a graph database environment, the proposed model places the "closed find context" (such as a grave or hoard) at its center, conceptualized as an *E19 Physical Object*, and links it to associated entities including typological classifications —individual artefacts (*E22 Man-Made Object*), biological remains (*E20 Biological Object*), persons (*E21 Person*), materials (*E57 Material*)—and both relative and absolute chronological attributions. Particular attention is given to documenting bibliographic sources for chronological and typological assignments through *E31 Document*, ensuring transparency regarding interpretative frameworks and potential biases. The study ultimately demonstrates that ontological modeling not only enhances interoperability and Linked Open Data integration but also serves as an analytical tool, helping to identify structural relationships, implicit assumptions, and gaps within archaeological datasets.

The growing need for strong and interoperable heritage documentation systems has emphasized the importance of representing archaeological and epigraphical data in semantic frameworks. Building on this, a research study investigates how ancient funerary inscriptions can be formally represented using CIDOC CRM and its extensions (CRMtex), addressing both their physical characteristics—such as material, dimensions, shape, text, and symbolic elements—and their interpretative aspects, including chronology, textual content, and broader archaeological interpretations. The result of this study is focusing on a 5th-century AD Greek funerary inscription discovered in Ghor as-Safi (Byzantine Zoora/Zoara, modern Jordan) demonstrates the applicability of this modeling approach. The study models the inscription's production process, physical features, textual information (including original script, transcription, and translation), cultural content, dating, and current condition and location. By integrating archaeological and textual dimensions within a unified semantic structure, this work contributes to the development of comprehensive models and automated systems for archaeological and epigraphical documentation and data integration. [SPG+23]

Extending the use of CIDOC CRM beyond the documentation of architectural remains, the CIDOC Intangible Cultural Heritage Working Group identifies a significant gap in museum collection management systems related to the documentation of intangible cultural heritage (ICH), which is largely absent from object-centered documentation frameworks. Vernacular architecture forms an essential part of this gap through its associated knowledge, practices, and cultural meanings. Recognizing that many aspects of cultural heritage—such as practices, skills, knowledge systems, rituals, and oral traditions—cannot be fully or meaningfully represented through physical objects alone, the Working Group seeks to extend and refine the CIDOC CRM in order to support the semantic documentation of ICH within digital cultural heritage environments.

As a result, the Group had developed a draft application profile aimed at enabling the structured and inclusive registration of intangible cultural heritage in museum contexts, within semantic documentation. Consistent with the UNESCO 2003 Convention for the Safeguarding of Intangible Cultural Heritage, the Group emphasizes a process-based understanding of intangible heritage, modeling it through activities and social practices sustained by communities. This perspective enables the representation of cultural continuity, knowledge importation, and the dynamic relationships between communities and places. Additionally, it supports the semantic integration of intangible cultural practices with their material expressions of heritage, such as traditional construction techniques and vernacular architecture by supporting interoperability and richer semantic interpretation within CIDOC CRM–based digital cultural heritage systems.

Overall, the CIDOC Intangible Cultural Heritage Working Group addresses issues related to the semantic representation of intangible cultural heritage by proposing conceptual approaches for modeling living and evolving cultural practices. Its work contributes to the extension of CIDOC CRM's descriptive scope and supports the documentation and interpretation of cultural heritage across both tangible and intangible domains.

Within this broader context of extending CIDOC CRM to address both tangible and intangible aspects of cultural heritage, several domain-specific application profiles have emerged. Among these, ARMOS (Architecture Metadata Object Schema) represents an applied approach that focuses on the systematic documentation and management of architectural heritage. With emphasis on immovable monuments, historic buildings, and architectural complexes, the schema aims to connect lightweight descriptive standards with more formal ontologies by providing a practical yet semantically rich framework for recording architectural information. At its core, ARMOS adopts an object-oriented approach, distinguishing between three main domains: the architectural object itself (the monument or building), its associated documentation (archival material, plans, photographs, bibliographic references), and its management context (responsible institutions, legal protection frameworks, conservation actions). This structure ensures that both the tangible aspects of an architectural work and the intangible elements of its historical significance and administrative treatment can be systematically represented.

The schema places strong emphasis on typology and use, enabling buildings to be classified not only by architectural form and style but also by their functional phases and historical transformations. In addition, ARMOS incorporates metadata for designation, cultural significance, and legal status, supporting the requirements of heritage institutions to record values and protection measures alongside descriptive information. A further characteristic of ARMOS is its interoperability. While designed to be practical for local repositories and institutional databases, it aligns conceptually with international metadata standards and ontologies such as CIDOC CRM, Dublin Core, CDWA Lite et cetera. This allows repositories adopting ARMOS to integrate into broader digital infrastructures for cultural heritage while maintaining a manageable descriptive schema.

The ARMOS (Architecture Metadata Object Schema) model was presented and discussed in the context of metadata interoperability for architectural heritage at the 7th Metadata and Semantics Research Conference [AK13].

2.1 Architectural Styles Model Approach and Vernacular Architecture Model Approach Differences

Research on the semantic documentation of architecture within CIDOC CRM has emphasized architectural styles and historical periods, modeling them as structured, named entities. In this framework, architectural styles are seen as historically defined phenomena, shaped by formal design principles, broader cultural and intellectual influences and are associated with specific creators-architects, schools, or architectural traditions. Both CIDOC CRM–based models view architecture mainly in terms of styles, examining how they evolve over time, influence one another, and relate to individual buildings. They, also, follow a top-down analytical approach, with the first model emphasizing in the architectural style through the eye of the historical period in which they were developed.

This first model demonstrates its ability to support the representation of international and formal architectural styles, ensuring clear style definition, historical timeline and theoretically grounded classification and interpretation. As an outcome, architectural styles are modeled as conceptual entities with temporal and spatial extent, linked to materials, construction techniques, and representative buildings. In this way, comparative analysis between periods and regions is achieved and interoperability between architectural heritage datasets is enhanced.

In comparison, vernacular architecture presents a fundamentally different case. Unlike formal architectural styles, vernacular architecture does not emerge from codified design theories or professional architectural discourse. It develops through long-term, collective processes grounded in local knowledge, environmental adaptation, material availability, and socio-cultural practices. As a result, architectural style–oriented models struggle to capture vernacular architecture, which lacks clear stylistic boundaries, identifiable creators, and formal design frameworks.

In response to these limitations, this thesis proposes a CIDOC CRM–based data model specifically designed for the documentation of vernacular architecture. This model focuses on the environmental, social, and cultural contexts, along with the shared building practices and intangible knowledge systems, that shape vernacular architecture. Rather than being treated as a derivative or informal variant of architectural style, the model, that will be analyzed in chapter 4, conceptualizes vernacular architecture as a dynamic cultural phenomenon shaped by environmental conditions, social organization, and intergenerational knowledge transmission.

The proposed model adopts an approach by decomposing traditional architecture into its constituent elements, including construction techniques, materials, morphological patterns, typological implications and associated cultural practices. With the help of

CIDOC CRM classes and properties, it allows for the integration of both tangible and intangible dimensions of traditional architecture. Particular emphasis is placed on modeling the relationships between architectural practices and cultural communities, as well as the environmental conditions that influence the architectural form of each construction. Furthermore, the model supports the representation of relationships between local architectural traditions, allowing the documentation of adaptations, regional variations and historical continuities without imposing rigid stylistic hierarchies. This model broadens CIDOC CRM to better represent culturally grounded architectural practices.

Chapter 3 CIDOC Conceptual Reference Model

In this chapter, the CIDOC Conceptual Reference Model (CIDOC CRM) is introduced in order to clarify its conceptual foundations, scope, and overall structure. Based on the review of existing modeling approaches presented in the previous chapter, this discussion outlines both the capabilities and the limitations of CIDOC CRM when applied to architectural heritage. Despite its ability to represent complex relationships, the model requires a clear understanding of its goals and principles to be used effectively. This is especially important for domains such as traditional architecture, which is shaped by process-oriented phenomena and cultural practices. The overview presented here establishes the theoretical basis necessary for understanding the modeling decisions adopted in the following chapters of this thesis. The discussion that follows introduces the CIDOC Conceptual Reference Model, focusing on its definition and main aims.

3.1 Definition of CIDOC CRM

The CIDOC Conceptual Reference Model (CIDOC CRM) is a structured and formal ontology created to model and represent diverse cultural heritage information. It aims to enable the integration of various datasets, assist in connecting different documentation standards, boost teamwork across many cultural heritage areas, and let systems and organizations share information seamlessly. By offering a standard setup, CIDOC CRM helps to organize and link different sources of cultural data in a structured way. This ensures that people can access, share, and study important historical and heritage-related facts more easily.

To best of our knowledge, there is currently no inclusive conceptual model that systematically covers a broad range of architectural styles and historical periods within the CIDOC CRM framework. While CIDOC CRM stands out in structuring relationships and mappings between different heterogeneous sources, its application in the domain of architectural history remains relatively unexplored in terms of a complete model that can entirely categorize and connect architectural styles across various periods and cultural contexts.

Yet, CIDOC CRM has been praised extensively as a well-functioning conceptual model to facilitate complex interrelations and create mappings between various sources of cultural heritage data. Example implementations include mappings from Encoded Archival Description (EAD) to CIDOC CRM [BG11], Visual Resources Association (VRA) mappings [GG12], and mappings with Dublin Core metadata standards. These evaluations reflect how CIDOC CRM has the potential to connect different documentation models, thus contributing to improving the interoperability of cultural heritage data globally.

CIDOC CRM makes it possible to reconstruct and interpret the past on a human scale, across different heterogeneous sources. These include a variety of data, from written texts and audiovisual material to oral traditions. Although its origins lie in the documentation and research of museum-based object collections, its greater goal is to develop semantic definitions and clarifications that help turn the fragmented and localized data of today into a single global data resource. Rather than dictating what cultural heritage institutions should document, CIDOC CRM clarifies the logic behind existing documentation practices, ensuring semantic interoperability across different systems. To support this goal, CIDOC CRM adopts a relationship-based approach, emphasizing the explicit representation of connections between entities rather than individual data elements. In this way, the model allows for meaningful interpretation while ensuring semantic interoperability between different systems.

3.2 Objectives and Scope of CIDOC CRM

The CIDOC CRM also serves as a technical framework, depicting how seemingly unrelated entities are semantically and logically connected in the field of cultural heritage documentation. It provides a structured approach that helps understand what kind of relationships can exist between different types of information, and ensures that databases will be able to answer complex intellectual queries without losing information. Through the establishment of a standardized approach for organizing and linking data, CIDOC CRM promotes and supports the coherence and accessibility of cultural information, making it easier to exchange, integrate, and interpret across various systems and institutions.

One of the primary functions of the CIDOC CRM is to offer guidance to information system developers, ensuring they align with effective approaches to conceptual modeling. This ensures that institutions dealing with cultural heritage—such as museums, archives, and research organizations—can maintain consistency in data representation and retrieval.

Additionally, CIDOC CRM acts in the role of a shared language between domain experts and IT developers, permitting them to work together in defining system requirements and ensuring accurate management of cultural content. By using a systematic approach to information representation, it becomes easier to identify shared data elements across different formats. This capability is especially useful for automating data transformation processes, ensuring seamless migration from legacy systems, improving data exchange, and integrating different sources without losing essential meaning. It supports long-term interoperability, allowing information to be maintained, shared and accessed consistently over time and across technological changes. This ensures that data can be transformed without loss of meaning.

Furthermore, CIDOC CRM helps users to show how different pieces of information are connected to each other. By offering a clear model of key entities, such as events, objects, and people, and their relationships, it allows users to create complex queries that uncover meaningful connections between different data resources. It is also believed that natural language processing algorithms and heuristic techniques can be supported by offering a structured model that can aid in transforming free-text information into logical, structured representations. However, the model is not intended to replace academic narratives full of context but rather to assist in identifying and linking related data more effectively. With the support of structured data management and advanced computational methods, the CIDOC CRM ensures that cultural heritage information remains understandable and usable in a dynamic digital landscape.

When working with CIDOC CRM, users should keep in mind that building data entry systems requires using terminology specific to the community, clear guidelines on what to document and in which order, and consistency checks tailored to the application. These features aren't provided by CIDOC CRM itself. However, its structured and adaptable framework allows users to create custom extensions, making it easier to meet the unique needs of different cultural heritage communities and applications.

The CIDOC CRM is designed to organize and structure knowledge about the past in a way that is clear and meaningful. It is divided into two main levels: the intended and the practical scope. The first scope establishes broad and inclusive principles that can be applied across different contexts, while the second one focuses on specific documentation standards and practices that CIDOC CRM is designed to describe. The practical scope is always guided by the intended scope, since it describes the range of growing, well-defined documentation standards and practices. Relying on this approach, CIDOC CRM is a useful tool for sorting historical data so that it can be linked, analyzed and exchanged between different systems and institutions.

The intended scope of the CIDOC CRM covers all essential information for integrating and exchanging heterogeneous scientific and scholarly documentation about the past, as well as what is being documented. CIDOC CRM aims to exchange relevant information with libraries and archives and align with their models, but administrative data, like staff records, finances, and visitor statistics, are not part of the CIDOC CRM's scope.

It is necessary, first, to define "scientific and scholarly documentation". With this term, CIDOC CRM clarifies that it's in a position that can handle detailed and high-quality information suitable for academic research. This doesn't exclude information for the public, but focuses on providing the detail and accuracy needed by museum experts and researchers. Following, the "documented and empirical evidence that supports it", refers to materials collected and displayed by museums, including objects, sites, monuments, and intangible heritage related to areas like history, art, archaeology, and science, as defined by ICOM. Documentation implies detailed descriptions of items, collections, or groups, including intangible heritage. It covers their current state and history. CIDOC CRM adds context, such as historical and geographical background, to give more value to these collections.

In contrast, the practical scope of CIDOC CRM is based on reference and commonly used standards for documented knowledge. It ensures that data encoded in these formats can be expressed in a CIDOC CRM-compatible way, keeping the same meaning. Keeping in mind that CIDOC CRM follows a progressive development, starting with widely recognized and well-established concepts commonly used by domain experts, the above separation is based on two key reasons. As a starting point, the goal is to prevent faulty adaptations and uncertainty when defining broad concepts in a large area, while keeping the ideas stable. Afterwards, it offers a tool for detecting and maintaining the attention of more important to the communities' concepts using the CIDOC CRM, while also supporting a clear framework for its advancement.

To fully benefit from CIDOC CRM's semantic interoperability, users should ensure that their data structures follow its standards, whether the data needs to be used in one system or shared with others. Data is considered conformant if it is structured using a formal language that keeps the relationships, properties, and hierarchy rules defined by this International Standard. This keeps systems consistent and compatible. However, it is not necessary to totally match all local documentation formats or include every concept and structure from the standard. CIDOC CRM is intentionally designed to be flexible, allowing both extensions to accommodate the complexity of cultural documentation and simplifications where necessary for efficiency. Systems that support only some of the defined subclasses and subproperties are considered partially conformant. Designers should document which parts their system supports.

The central purpose of CIDOC CRM is to help exchange and manage structured information. It doesn't require turning free text into structured formats, though unstructured data can still be included, just not part of the conformance specifications. Regardless of its internal structure, any documentation system meets the CIDOC CRM standard, if its data can be reliably converted into the CRM format without losing any meaning. This implies that both designers and users agree the transformed data still follows the definitions set by the standard, although there are no specific requirements for how the data should be transformed.

3.2.1 Property Quantifiers

CIDOC CRM is designed to support alternative views and the use of incomplete information. As a result, all properties must be implemented as optional and repeatable for their scope and range. With the aim of semantic explanation, property quantifiers are provided. Property quantifiers are auxiliary concepts that express the number of possible uses of an instance of a scope or range of a property. They are named using a numeric (0, 1 or n) notation and a verbal (One, Many, Required, or Dependent). The verbal terms "One", "Many", "Required" and "Dependent" are used. The terms "One" and "Many" indicate the number of possible uses of the instances, the term "Required" indicates the necessity of using an instance, while the term "Dependent" indicates that a value field instance does not exist without the presence of the corresponding property instance.

3.2.2 Terminology

The CIDOC CRM conceptual model consists of a vocabulary with commonly defined terms that is applied by users during the modeling process and helps to avoid any misunderstandings and errors. It also facilitates the understanding of the model by specialists and non-specialists (ICOM/CIDOC, 2021). Through the model, specialization is sought. That is, users have the ability to proceed to descriptions that may contain the appropriate meaning through the specializations of the entities or, otherwise, the subclasses (see definition below). Of course, because the model is not in a final stage, specialization is not always possible, thus making the absolute accuracy of the descriptions impossible. This terminology is compatible with that of the RDF language. The necessary definitions are listed below:

Class: Also referred to as Entity or Concept (Entity). It is a category of objects that share one or more common characteristics and act as criteria for identifying objects belonging to that class. The set of these characteristics is called the intension of the class. A class can be a scope or a range (see definition below) for none, one, or more properties formally defined in the model. A class collaborates with a set of open-world hypotheses of real-world instances, known as the extension of the class. The instances of a class are unlimited and can be continuously increased. Thus, a class cannot be defined by enumerating its instances. The class plays a role similar to that of a noun in a sentence, and does not require its association with any other element of the model, unlike properties (see definition below), which require the existence of a scope and a range for their proper functioning. CIDOC CRM defines entity types and gives them short labels. Thus, the prefix "E" is used for the class followed by a number and a unique code in the English language. The unique code consists of a noun phrase written in the title case (the initial letters in capital letters). An example of a class is the *E7 Activity*.

Subclass: It is a specialization of another class (its superclass). It inherits all the properties and instances of the superclass without exceptions (Strict Inheritance). It can have more than one superclass and in this case it inherits the properties of all its superclasses (Multiple Inheritance). The content of the subclass is the extension of its content. The IsA relationship (i.e. the association of a class and a subclass) or specialization between two or more classes creates a structure known as a class hierarchy. The IsA relationship is transitive and may not be cyclic. In some contexts, (such as the C++ programming language) the term derived class is used as a synonym for subclass. An example of a subclass is *E11 Modification*, a subclass of *E7 Activity*.

Superclass: It is a generalization of one or more other classes (its subclasses), meaning that it inherits all the properties and instances (see definition below) of its subclasses, and that it may also have additional instances that do not belong to any of its subclasses. E1

CRM Entity is an example of a superclass, which is a superclass of all CIDOC CRM classes.

Intention: It is the intended meaning of a class or a property. It consists of one or more common characteristics that are shared by all instances of the class or property. These characteristics do not need to be explicitly stated in logical terms, but can be described in a text (the scope note) that constitutes the description of the content.

Extension: It is the set of actual instances that belong to a class. Due to the indefinite number of instances of a class, the extension is characterized as open. An information system can at any time refer to an instance of a class, which forms a subset of its extension.

Scope Note: It is the text describing the content of a class or property. It is provided to explain the purpose and application of CIDOC CRM classes and properties, as well as clarify the usefulness of a class or property among different possible interpretations. Examples of class and property instances are also provided to facilitate the understanding and application of a class or property.

Instance: A real object that meets the criteria of a class's content. An instance of a property is a relationship between two other instances, one for the definition domain and one for the value domain meeting the criteria of the property's content. There are two main branches in CIDOC CRM: things that have a permanent identity - such as physical objects, ideas and concepts - and temporary concepts or phenomena that usually occur within a limited time frame (an event or activity). The latter usually refer to events. For example, a person's identity endures despite their death. Death is a permanent concept, but events that occurred during a person's physical life are also examples of things bound by some period of time.

Property: The relationship that links two classes together. It is often referred to as an association. It is characterized by a content, which is described by field notes. It is defined by references to the domain and the value domain, which take the positions of the subject and object respectively. The logical order that a property follows is to start from the domain and end in the value domain, but this does not mean that the reverse cannot apply (inverse property). The choice of the class that will constitute the domain does not depend on any rule and the same happens for the value domain. This results in a property being formulated in two equally correct ways. Properties in turn can have their own properties that are related to other classes and are specialized in the same way as classes, resulting in relationships between sub-properties and super-properties. The prefix “P” is used to name properties followed by a number and a unique code in the English language. When it comes to a state, properties are named in the present tense, while when it comes to events, they are named in the past tense. Properties that share a common domain and a common range are called symmetric or transitive. More specifically, a symmetric property expresses the same relationship in both the domain-to-value-domain and the value-to-definition-domain directions. An example of this is *E53 Place*. *P122 borders with*: *E53 place*. The names of symmetric properties do not have parenthetical form, because reading in the direction of the range-to-domain is the same as reading in the direction of the range-to-value-domain.

Inverse Property: It is the restatement of the property from the range to the domain without any more general or specific meaning. It is not a new property in itself and defines the inverse relationship from the original property. For example, the property *P4 has time-span* has as its inverse property *P4i is time-span of*.

Subproperty: It is a specialization of the superproperty and an extension of its content, from which it inherits all its properties without exception (Strict Inheritance). For example, the property *P141 assigned (was assigned by)* is a subproperty of *P42 assigned (was assigned by)*. Because it can have more than one superproperty, it also inherits their properties (Multiple Inheritance). All instances of a subproperty are also instances of the superproperty and its definition and value fields are the same as the corresponding definition and value fields of the superproperty and of its subclasses. The specialization between two or more properties is transitive and creates the template hierarchy.

A property can also function as a subproperty of the inverse of another property. In this case, the instances of the subproperty are also instances of the inverse of the other property and their content is expanded. But here the scope is the same as the range of the other property or the subclass of the range, while the range is the same as the range of the other property or the subclass of the range. The subproperty inherits the definition of all properties declared for the other property without exceptions (Strict Inheritance), except that it has none, one or more properties of its own. The definitions of the inherited properties must be interpreted in the reverse sense of the orientation of the subproperty, i.e. from the range to the scope.

Superproperty: It is the generalization of one or more other properties (it's subproperties) or their inverses, meaning that it subsumes all instances of its subproperties, but may include instances that do not belong to any of its subproperties.

For example, the property *P31 has modified (was modified by)* has as subproperties *P108 has produced (was produced by), P110 augmented (was augmented by)* and *P112 diminished (was diminished by)*. Its content is less restrictive and the subsuming or generalizing relationship is the inverse of specialization.

Domain: It is the class for which a property is formally defined and the choice of the appropriate class in each case does not depend on any rule. This means that the instances of the property apply to the class that functions as the domain. For example, *P31 has modified (was modified by)* has the *E11 Modification* class as its scope. A property must have only one scope, even if the class chosen as the scope includes instances for which the property is not documented.

Range: It is the class that includes all possible values of a property, that is, instances of a property can only be linked to instances of this class. For example, *P31 has modified (was modified by)* has the *E18 Physical Thing* class as its scope. A property must have only one range, even if the range class includes instances that are not values of a property. The choice of the appropriate class in each case does not depend on any rule.

Monotonic Reasoning: A term from the methodology of knowledge representation. A form of reasoning is monotonic when an addition to the set of propositions that create the knowledge does not determine a reduction in the set of conclusions. In practical terms, if professionals subsequently enter correct statements into an information system, the system should not consider any result of these statements invalid when a new one is entered. CIDOC CRM is designed for monotonic reasoning and thus allows the merging of knowledge without conflicts.

Shortcut: A formally defined single property that represents a conclusion or connection from data paths to allow the user to describe instances for which they have less detailed knowledge than the full data path. It is introduced for instances where their documentation refers only to the conclusion and not to the full path followed. The field notes of all properties that are classified as overrides describe in words the equivalent conclusion. For each override, CIDOC CRM includes in its schema the properties of the full data path explaining the override. An example is the property *P2 has type* which is an override of the path *P41i was classified by*, *E17 Type Assignment*, *P42 assigned*, *E55 Type*.

Primitive Concept: A concept is characterized as primitive whose meaning is agreed upon, but is not determined by any logical inference from other concepts and is not subdivided. For example, mother can be described as a female human with one (at least) child. Therefore, mother is not a primitive concept. However, event is a primitive concept. Most of CIDOC CRM consists of primitive concepts. Most of CIDOC CRM is based on primitive concepts. Properties whose value range is a subclass of the *E59 Primitive Value* class do not have an inverse property.

3.2.3 Class and Property Hierarchies

CIDOC CRM does not declare attributes, although they are implicitly included in the Explanatory Notes of the classes, and characterizes each information element as an “attribute” or as a “relationship” between two classes. Despite the lack of comprehensive definitions, hierarchical representations of the IsA hierarchies of classes and attributes are used to understand and use the model.

The class hierarchy follows a structured format in which each class is identified by a unique identifier consisting of a number preceded by the appropriate letter (E, B, A, or S), depending on whether it is the base model or an extension of it. This identifier is followed by a series of dashes indicating the class's position within the IsA hierarchy. The English name of each class appears to the right of the dashes, while the number of dashes reflects the hierarchical level of the class, following an organization based on depth, from more specific to more general subhierarchies. Classes that appear in more than one position within the hierarchy, indicating multiple inheritance, are shown in italics. The class hierarchy of the model is presented in Table 2 of Appendix A.

The property hierarchy is similarly structured, following a structured format with its own appropriate rules. Thus, each property is identified by a unique identifier consisting of a number preceded by the letter "P". This identifier is followed by a series of dashes indicating the property's position within the IsA hierarchy. The English name of each property appears to the right of the dashes, accompanied by its reverse name in parentheses to support reading from scope to domain. Each property declaration specifies the domain class to which it applies and the corresponding scope class to which it refers. The hierarchy is ordered by hierarchical level in a manner that prioritizes depth, proceeding from more specific to more general subhierarchies, and by property number among properties at the same hierarchical level. Properties that appear in multiple positions within the hierarchy, indicating multiple inheritance, are shown in italics. The property hierarchy of the model is presented in Table 3 and the property of property hierarchy in Table 4 of Appendix A.

3.3 Applied Form

The CIDOC CRM is an object-oriented semantic ontology used in computer science and designed to be understandable by both documentation experts and information scientists. It can also be easily converted into machine-readable formats like RDF Schema or OWL. A documentation system that complies with CIDOC CRM can be applied using RDF Schema or OWL, but it can also be adopted in relational or object-oriented schemas. CIDOC CRM instances can be encoded in various formats, including RDF, JSON LD, XML, and OWL. Specifically, CIDOC CRM is expressed in terms of the core ideas of semantic data modeling, consisting of the following elements:

- *Classes*, which represent broad concepts within the domain of discourse, such as the CIDOC CRM class E21 "Person," which denotes the concept of a person.
- *Properties*, which define binary relationships between entities in the domain, such as the CIDOC CRM property P152 "has parent," which links a person to one of their parents.
- *Properties of properties*, such as P14.1 "in the role of," which is associated with the CIDOC CRM property P14 "carried out by" (see also the section on "About Types"). These properties do not appear in the standard property hierarchy but are included in the base property declarations and referenced in the class declarations.

CIDOC CRM includes 81 classes and 160 unique properties and is organized as a system where properties are inherited. If a property P connects class A to class B, it also applies to any subclasses of A and B. Sometimes, A and B share a common subclass C. In such cases, when the property is limited to C, it may become transitive.

Yet, some of the properties act as shortcuts of longer paths that connect the same domain – the class it applies to a property – and range – the class that includes all possible values for that property – classes as the shortcut property through one or more intermediate classes. For example, the property *E18 Physical Thing P52 has current owner (is current owner of) E39 Actor*, is a shortcut for a fully articulated path from *E18 Physical Thing* through *E8 Acquisition* to *E39 Actor*. An instance of the fully articulated path always implies an instance of the shortcut property. However, the inverse may not be true; an instance of the fully articulated path cannot always be inferred from an instance of the shortcut property inside the frame of the actual knowledge base.

In this assignment, in order to evolve a data model about vernacular architecture, certain classes and properties were used. The classes and the properties that were used in the data model were presented in Table 5 and Table 6 of Appendix B.

3.4 CIDOC CRM Extensions

The CIDOC CRM covers only a limited part of the broader real world, which is infinite in scope. To address this, the model is designed to be extensible by linking with compatible external type hierarchies. Some concepts, such as *E39 Actor* and *E30 Right*, are defined with less detail due to the model's specific focus. To ensure that any data structured under them remains valid within the core CIDOC CRM framework (CRMbase), the ontology uses some extensions. This guarantees search integrity, meaning that queries based on CIDOC CRM will return consistent results, whether data follows the base model or includes extensions.

CIDOC CRM offers several mechanisms to increase its scope on demand without losing compatibility. First, existing classes can be extended as subclasses or by the type hierarchy. Second, properties can be extended either as subproperties or using properties of properties that allow subtyping. Third, additional information not covered by the formal semantics of the CIDOC CRM can be recorded as unstructured data using *E1 CRM Entity* and the property *P3 has note E62 String*. Finally, the CIDOC CRM can be extended with superclasses and properties relevant to a broader scope, which are referred to as conservative extensions, when they maintain backwards compatibility with instances already described by the CIDOC CRM.

CIDOC CRM extensions refer to additions or modifications made to the core CIDOC CRM to address specific needs, expand its scope, or improve its adaptability for particular use cases. While CIDOC CRM is designed to be extensible to support a variety of specialized requirements from different sectors or domains, without however deviating from the character of the flexible, broad framework for cultural heritage documentation. These extensions allow users to define new classes, properties, or concepts that fit their specific needs while maintaining compatibility with the original CIDOC CRM structure. Moreover, improve the core CIDOC CRM model by adding specific details that the base model may not cover. They help adapt the CRM for areas like archaeology, art history, or social sciences while keeping the main principles unaffected. Extensions add new classes or properties, that fit with the CRM structure and remain compatible with data from the base model. They let the CRM ontology evolve without changing its basic structure.

Extensions must still follow the CIDOC CRM classes, so data from both the core CRM and extensions work together. Systems using both can still provide accurate results. For example, CRMarchaeo focuses on archaeological data, while CRMba is used for managing relationships between cultural heritage institutions and exhibitions. Extensions can also introduce new properties, like an artist's role in creating artwork or the origin of an artifact. Experts create extensions to keep the CIDOC CRM useful for different fields. This collaboration helps the model grow and adapt to cultural heritage needs. In short, extensions customize the model while keeping it flexible. Overall, CIDOC CRM extensions help adapt the model for different cultural heritage fields. They allow organizations to keep its flexibility and strength while adding specialized features.

Chapter 4 Description Model of Vernacular Architecture

In this section, the thesis introduces a CIDOC-CRM–based data model for vernacular architecture, aiming to describe the cultural, environmental, and use-related factors that shape vernacular building traditions. The model is conceived as a general and flexible framework that can be applied to different forms of vernacular architecture across a range of geographical, climatic, and cultural settings. Building on the semantic structure of CIDOC CRM, the approach enables the consistent documentation and comparison of architectural traditions that have developed in response to local conditions.

Rather than focusing exclusively on architectural form, the model also considers the processes of creation, use, change, and adaptation that influence vernacular buildings over time. Particular attention is given to the connections between architectural design, material choices, construction techniques, environmental conditions, and cultural practices. This perspective allows vernacular architecture to be understood as a living and context-dependent phenomenon, instead of a static physical object, while supporting both detailed documentation and broader analytical exploration.

As an initial case study, the traditional Mongolian yurt is used to illustrate the application of the proposed model in practice. Developed over centuries by nomadic communities in Central Asia, the yurt reflects the close relationship between architectural form, environmental conditions, material resources, and cultural practices. Its circular layout, portable structure, and use of locally available materials highlight a long process of adaptation to both climatic challenges and a nomadic lifestyle.

The Mongolian yurt serves as a suitable example for presenting the proposed model, as its construction is based on clearly defined architectural components, established building techniques, and cultural practices linked to its use and construction. These features make it possible to present the key entities, properties, and relationships of the model in a clear and accessible way. The application of the model to the Mongolian yurt is shown in Figure 1, which illustrates how cultural, environmental, and functional aspects of vernacular architecture can be semantically represented within the CIDOC CRM framework.

Figure 1: A traditional Mongolian Yurt

4.1 Model Description Case: Yurt

The Mongolian yurt is consistently employed as a representative case study for the demonstration and illustration of the proposed model in the accompanying figures. Its well-documented construction techniques, clearly identifiable components, and strong relationship to nomadic cultural practices and environmental conditions make it particularly suitable for showcasing the model's classes, properties, and semantic relationships. Through this example, the applicability, flexibility, and descriptive potential of the CIDOC-CRM–based approach are effectively demonstrated, highlighting its relevance for the structured documentation and comparative analysis of vernacular architectural heritage.

4.1.1 The Formative Context of Vernacular Architectural Practices

The formative context of vernacular architecture is rooted in the complex interplay between environmental conditions, microclimate, cultural practices, topography, available materials, and socio-economic structures over an extended time span. Developed over generations, often across centuries, vernacular architecture reflects a long-term process of adaptation in response to localized environmental factors, particularly microclimatic conditions and the physical landscape. A data model depicting the above context, based on CIDOC-CRM, is shown in Figure 2. In this data model, instances of vernacular architectures are classified as *E29 Design or Procedure*. A vernacular architecture style may be known with various names (depending on the region or language) which are represented in CIDOC CRM as instances of *E41 Appellation*. An appellation is related to *E29 Design or Procedure* though the property *P1 is identified by*. Alternative names or forms can also be included using the property *P139 has alternative form*.

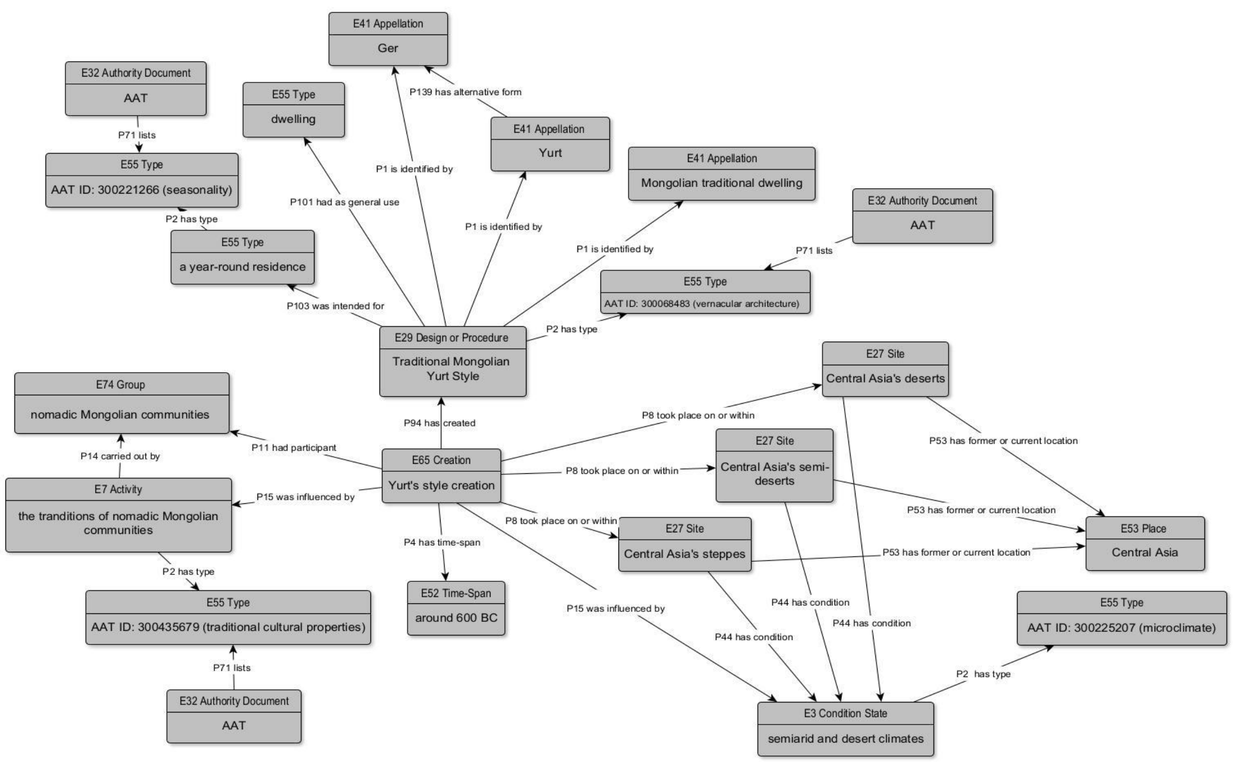

Figure 2: The creation of a vernacular style – Case study: Mongolian Yurt

The general use and intended function of a vernacular style is expressed by linking the instance of *E29 Design or Procedure* to instances of *E55 Type*, using the properties *P101 had as general use* and *P103 was intended for*, respectively. Moreover, the creation of a vernacular architecture style, is expressed through the class *E65 Creation*. To indicate the temporal presence of this style, we link its creation (*E65 Creation*) to the class *E52 Time-Span* using the property *P4 has time-span*.

The assertion that the style was influenced by the cultural practices (*E7 Activity*) of a specific cultural community (*E74 Group*) is modeled by linking the *E65 Creation* to *E7 Activity* via the property *P15 was influenced by*, and by linking the *E7 Activity* to *E74 Group* using the property *P14 carried out by*. Additionally, the creation (*E65 Creation*) of the style is associated with a cultural group (*E74 Group*) through the property *P11 had participant*.

In our data model, the topographical conditions are represented by linking the creation of the style (*E65 Creation*) to the class *E27 Site* through the *property P8 took place on*. These site instances are, in turn, connected to the class *E53 Place* via the property *P53 has current or former location*, allowing the spatial context to be defined. Lastly, the elements of the environmental context (*E3 Condition State*) of vernacular architecture style are represented in our data model by linking the creation (*E65 Creation*) directly to *E3 Condition State* via the property *P15 was influenced by*. Additionally, *E27 Site* is connected to *E3 Condition State* through the property *P44 has condition*, capturing the environmental state of the location. In turn, *E3 Condition State* is linked to *E55 Type* to specify the nature or type of the condition (e.g. microclimate).

For example, the Mongolian Yurt (*E29 Design or Procedure*), depicted in Figure 2, illustrates how architectural form emerges from cultural, environmental, and social contexts. The Mongolian Yurt —also known as *ger* or more generally as the dwelling of Mongolians (names are instances of the class E41 Appellation connected to corresponding *E29 Design or Procedure* through the property *P1 is identified by*)— was developed as a year-round residence (that reflects the needs and lifeways of nomadic communities. The Yurt style (*E29 Design or Procedure*) is connected to its creation, represented as an instance of *E65 Creation*, through the property *P94 has created*. This creation is originating around 600 BCE, and is represented as an instance of *E52 Time-Span* connected to *E65 Creation* through the property *P4 has Time-Span*. In this creation nomadic Mongolian communities (represented as an instance of *E74 Group*) has participated (*P11 had participant*). The creation shaped (*P15 was influenced by*) by their traditions and daily activities (*E7 Activity*). This architectural form evolved (*P8 took place* *on or within*) across the steppes, semi-deserts, and deserts of Central Asia (all of them are instances of *E27 Site*), within the broader region now known as Central Asia, represented as instance of *E53 Place* connected to *E27 Site* through the property *P53 has former or current location*. The Yurt's design responds directly (*P15 was influenced by*) to the open, windswept topography of the steppe and its extreme climatic variability, particularly semi-arid and desert conditions (*E3 Condition State*), also related to the corresponding instances of *E27 Site*, through the property *P44 has condition*. This condition state is a type (*E55 Type*) of microclimate, making it a compelling case study in how environmental and cultural factors shape vernacular architecture.

4.1.2 Constructional, Morphological and Typological Consistencies of Vernacular Architecture

Vernacular architecture style displays consistent constructional, morphological, and typological patterns rooted in local traditions, environmental adaptation, and cultural continuity. It employs local materials and traditional techniques, features functional and climate-responsive forms, and includes recurring building types for domestic, agricultural, or communal use. Decorative elements often reflect local identity. These consistencies contribute to structural resilience, environmental harmony, and cultural coherence across time and place. Figure 3 illustrates the data model based on CIDOC CRM classes and properties, use to document the aforementioned consistencies.

Techniques, decorations, and patterns (plans) used in a specific vernacular style are all modelled as instances of the *E29 Design or Procedure* class. These instances are classified through the class *E55 Type* and are related to the corresponding style through the property *P46 is composed of*. In the case an instance of *E29 Design or Procedure* represents a technique this instance is connected to a functionality (represented as an instance of *E55 Type*) through the property *P101 had as general use*.

Each instance of *E29 Design or Procedure* classified as a technique is linked through the property *P68 foresees use of* to (one or more) instances of the class *E57 Material*, in order to indicate the materials involved in the technique. Furthermore, to document specific characteristics of these materials, *E57 Material* is connected *to E26 Physical Feature* via the property *P130 shows features of*.

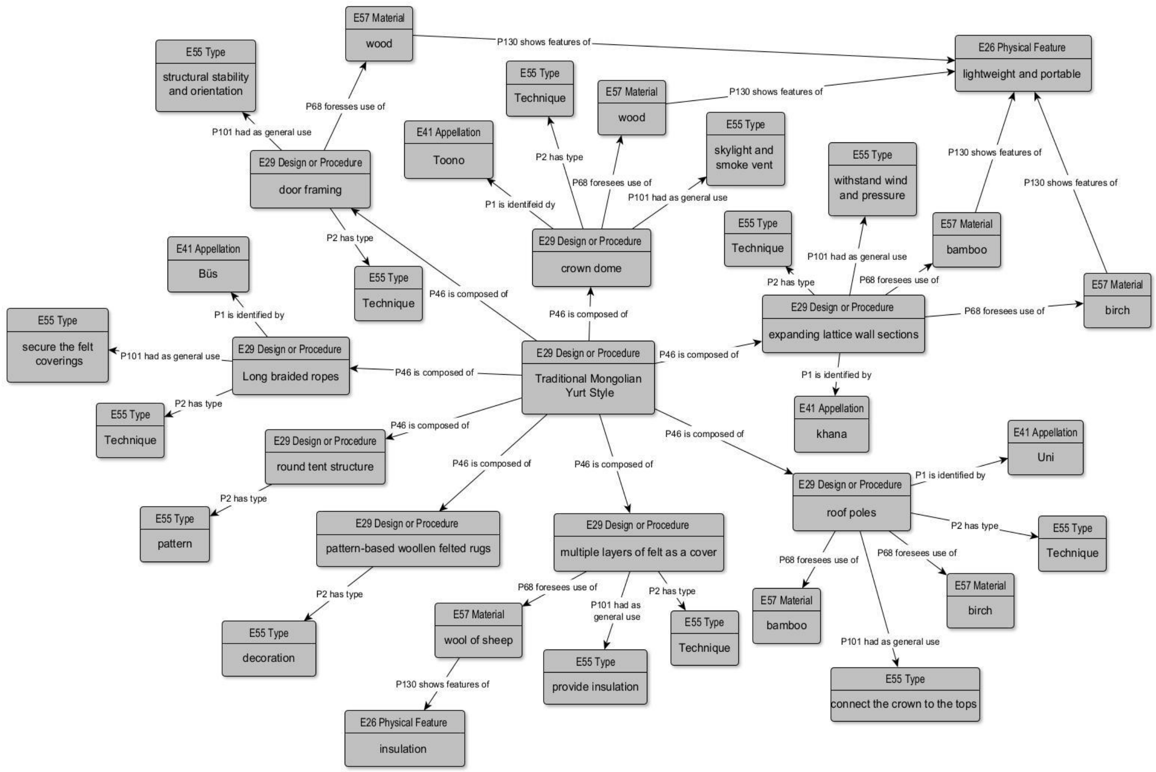

Figure 3: The components of a vernacular style – Case study: Mongolian Yurt

In that case of study, the construction of a Mongolian yurt, or ger, reflects a highly efficient and portable architectural system developed by Central Asian nomads. It begins with a sturdy, rectangular wooden door frame (*E29 Design or Procedure*), classified as a technique (denoted as an instance of *E55 Type*). The door frame is constructed from wood, and this is expressed by connecting the corresponding instance of *E29 Design or Procedure*, with instance wood of the class *E57 Material*, through the property *P68 foresees use of*. This component is lightweight and portable which is denoted as an instance of the class *E26 Physical Feature* which is connected to the *E57 Material* with the property (*P130 shows features of*), and provides (*P101 had as general use*) structural stability and orientation (*E55 Type*). Surrounding this is a series of expandable wall sections (*E29 Design or Procedure*), called *khana*, which are also constructed from lightweight and portable wood traditionally bamboo or birch. These lattice-like frames unfold to form a circular wall that is flexible yet strong, allowing the yurt to withstand wind and pressure. At the center of the structure sits the *toono*, a circular crown (*E29 Design or Procedure*) that functions as both a skylight and a smoke vent. Radiating from the *toono* are roof poles (*E29 Design or Procedure*), known as *uni*, which connect the crown to the tops of the *khana*, forming a stable conical roof. Once the wooden frame is in place, it is covered with multiple layers of felt, known as *esgii* (*E29 Design or Procedure*), typically made from (*P68 foresees use of*) compressed sheep's wool (*E57 Material*), providing excellent insulation (*E26 Physical Feature*) against Mongolia's harsh climate. A key element of morphological consistency in the interior of a Mongolian yurt is the use of patterned woolen felt rugs (*E29 Design or Procedure*) as decoration (*E55 Type*). Finally, from a typological perspective, categorized as pattern (*E55 Type*), the Mongolian yurt belongs to the category of round tent structures (*E29 Design or Procedure*).

4.1.3 Relating Vernacular Architecture Styles – Drawing in Parallels

Relating vernacular architecture styles across different regions reveals a network of shared principles shaped by common environmental challenges, material constraints, and cultural practices, despite variations in form and appearance. Drawing parallels among these styles uncovers patterns in construction techniques, spatial organization, and material usage that transcend geographic boundaries. These relationships are not merely superficial similarities but arise from deeply embedded principles of adaptation, resilience, and cultural expression. Moreover, vernacular architecture continues to influence contemporary construction. The Modern Yurt stands as a prime example of this continuity and reinterpretation in architectural design.

In this data model, the above relationships are represented by connecting instances of the *class E29 Design or Procedure* via the property *P69 has association with* and further qualifying the nature of this association using the property (of property) *P69.1 has type*, which links to an instance of *E55 Type*. This allows the specification of the precise kind of relationship being expressed. In order to represent that a specific vernacular prototype (expressed as an instance of *E29 Design or Procedure*) gives rise to another vernacular style (another instance of *E29 Design or Procedure*) we relate the creation events (instances of *E65 Creation*) that created (*P94 has created*) each vernacular style, with the property *P17* *was motivated by*, reflecting conceptual or stylistic influence, and

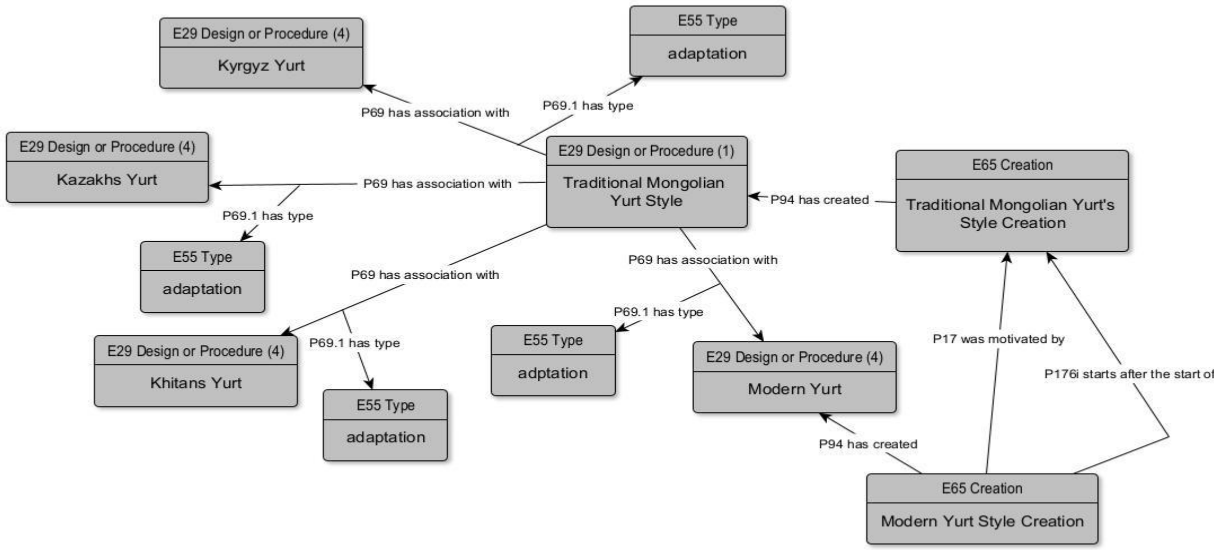

Figure 4: Relating Vernacular Architecture Styles – Case study: Mongolian Yurt

the property *P176i starts after the start of*, which establishes a temporal sequence between the two creation events. Besides, the corresponding instances of *E29 Design or Procedure* are associated via the property *P69 has association with*, which is classified (using the property of property *P69.1 has type*) as adaptations which is represented as an instance of *E55 Type*.

Continuing the example with the Yurt, as illustrated in Figure 4, the Mongolian Yurt (*E29 Design or Procedure*) serves as the prototype for a family of nomadic dwellings across Central Asia. The yurts of the Kyrgyz, Kazakhs, and Khitans also modeled as instances of *E29 Design or Procedure* —are associated with this prototype via the property *P69 has association with*, and are classified, using *E55 Type*, as adaptations. These Yurts represent cultural modifications shaped by environmental pressures, material availability, social organization, and symbolic meaning. Such adaptations are not deviations, but rather regional evolutions of a shared nomadic architectural technology, grounded in the practicality and symbolism of the original Mongolian yurt. The creation (*E65 Creation*) of the modern Mongolian yurts (*E29 Design or Procedure*), was motivated (*P17 motivated by*) and followed (*P176i starts after the start of*) the creation of the traditional Mongolian yurt style (*E29 Design or Procedure*). This creation, in turn, gave rise to (*P94 has created*) a Modern Yurt (*E29 Design or Procedure*), which is also classified as an adaptation (*E55 Type*) of the original archetypal form.

4.1.4 Relating Constructions to Vernacular Architecture Styles

Vernacular structures (e.g., houses, barns, and community buildings) can be systematically classified and linked to one or more vernacular architectural styles. These constructions often exhibit distinctive architectural features that are readily identifiable and closely tied to specific cultural practices. To support the semantic representation of such relationships, a data model based on the CIDOC CRM is proposed, as illustrated in Figure 5. This data model employs the CRMba extension, specifically the classes *B1 Built Work* and *B2 Morphological Building Section*, both of which are subclasses of *E24 Physical Human-Made Thing*. The *B1 Built Work* class represents complete architectural entities whose creation is modeled using the *E12 Production* class and is informed by particular vernacular architectural traditions. In contrast, the *B2 Morphological Building Section* class captures discrete components or sections of constructions that embody design principles characteristic of specific vernacular practices.

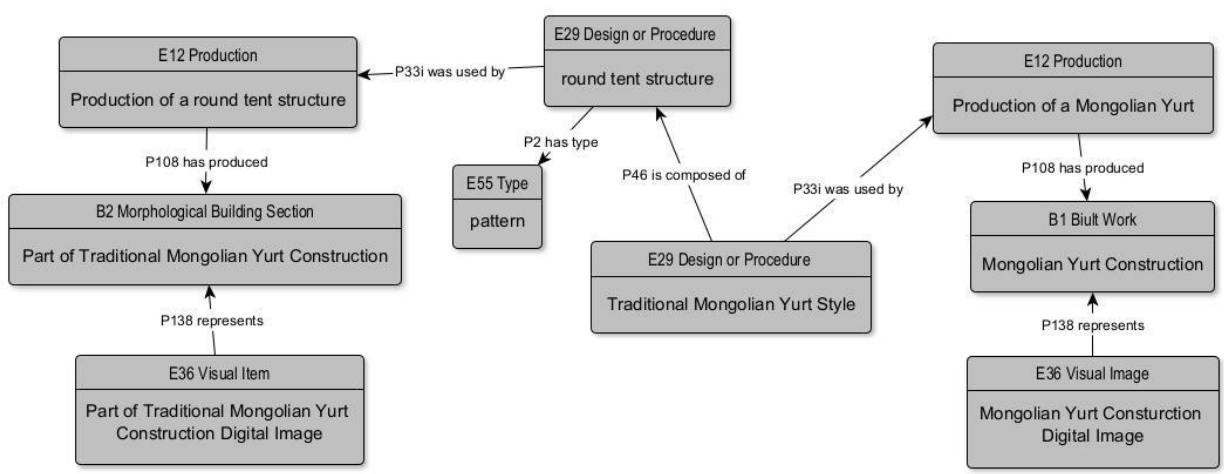

Figure 5: Relating Constructions to Vernacular Architecture Styles - Case study: Mongolian Yurt

In the example presented in Figure 5, the Mongolian Yurt is modeled as an instance of *E29 Design or Procedure* and is associated with a specific constructed example represented by *B1 Built Work*. This association is further contextualized through a digital representation (*E36 Visual Item*) that depicts the yurt. Additionally, a *B2 Morphological Building Section* is included to represent a construction component - such as the circular tent structure - whose production reflects the morphological and structural principles inherent to the Mongolian Yurt tradition (*E29 Design or Procedure*). A contemporary architectural example influenced by this tradition is the Great Court Roof of the British Museum. Its circular layout, lightweight steel-and-glass canopy, and central oculus reflect spatial and structural concepts reminiscent of the Mongolian Yurt, adapted to a modern institutional context.

4.2 Model Description Case: Igloo

The igloo is an exceptional example of the vernacular architecture of the Arctic, deeply connected with environmental, social and cultural conditions of Inuit indigenous communities. As an architectural practice, igloo does not come as a result of a theoretical design or a personal architectural conception. The final outcome arises for the collective knowledge transmitted from generation to generation and evolves through the continuous interaction between humans and harsh natural environment.

The creation of an igloo is directly associated with the climate conditions Central and Eastern Arctic, where the remarkably low temperatures, severe winds and the absence of conventional building materials established the use of snow as a core construction material. Snow, cut into compact blocks, operates concurrently in the manner of structural and insulating material, applying its natural attributes for heating maintenance on the shelter's interior. The domed, nearly hemispherical form of the igloo ensures structural stability and effective resistance to wind forces, while also contributing to the uniform distribution of heat.

4.2.1 The Formative Context of an Igloo as a Vernacular Architectural Practice

This conceptual model frames the creation context of the igloo as a vernacular style, developed according to the CIDOC CRM framework. At the center of the model lies the Igloo Style, represented as an instance of *E29 Design or Procedure*, which serves as the focal point for the articulation of naming conventions, functional use, cultural attribution, spatial distribution, temporal framing, and environmental conditioning. The igloo style is identified by multiple names that reflect different cultural and linguistic contexts, each modeled as an instance of *E41 Appellation* and linked to the central *E29 Design or Procedure* via the property *P1 is identified by*. These appellations include terms such as *iglu, igluvigag, snow house, and Traditional Inuit snow house*. The presence of alternative linguistic forms is explicitly captured through the property *P139 has alternative form*, allowing the documentation of terminological variation across regions and languages.

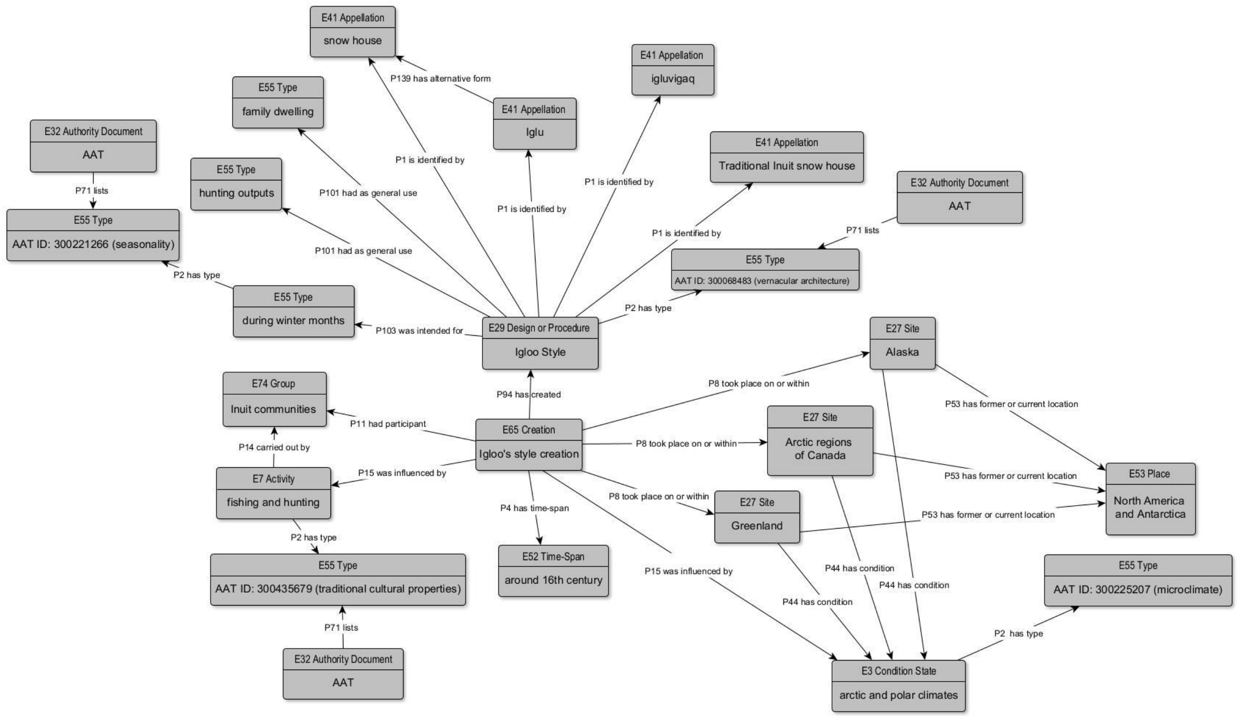

Figure 6: The creation of a vernacular style – Case study: Igloo

In parallel, the igloo style is classified within broader conceptual categories by linking it to instances of *E55 Type*. It is associated with the Getty Art & Architecture Thesaurus (AAT) concept of vernacular architecture (*AAT ID: 300068483*), referenced through an *E32 Authority Document* and connected via the property *P71 lists*, ensuring terms remain consistent and can be clearly understood across systems by the experts.

The functional dimension of the igloo is depicted through its association with several instances of *E55 Type*, in Figure 6, which describe both its general use and its intended purpose. Through the property *P101 had as general use*, the igloo style is linked to functions such as family dwelling and hunting outputs, reflecting its role in domestic life and subsistence activities. Additionally, its seasonal character is captured by associating it with the type during winter months, which is further classified under the concept of seasonality. The intended temporal use of the igloo is expressed via the property *P103 was intended for*, emphasizing its function as a winter habitation specifically adapted to extreme cold conditions.

The creation of the igloo style is represented through an instance of *E65 Creation*, labeled as Igloo's style creation, which is linked to the *E29 Design or Procedure* via the property *P94 has created*. This creation event is temporally situated through its connection to an instance of *E52 Time-Span*, approximately dating the formation of the style to around the 16th century, using the property *P4 has time-span*.

Cultural agency is central to the model. Inuit communities are represented as an instance of *E74 Group* and are linked to the creation event through *P11 had participant*, indicating their direct involvement in the development of the architectural style. The everyday subsistence practices of these communities—specifically fishing and hunting—are modeled as *E7 Activity* and are connected to the creation event via *P15 was influenced by*, while the activities themselves are associated with the Inuit communities through *P14 carried out by*. These relationships emphasize that the igloo emerged as a direct response to culturally embedded practices rather than as an abstract architectural concept.

The spatial dimension of the igloo's creation is expressed through multiple instances of *E27 Site*, including Alaska, Greenland, and the Arctic regions of Canada. The creation event is linked to these sites using the property *P8 took place on or within*, indicating that the architectural style developed across a broad yet environmentally consistent geographic area. Each site is further connected to a broader geographic entity, North America and Antarctica, modeled as *E53 Place* and linked via *P53 has former or current location*, situating the igloo within a wider continental context.

Environmental conditions play a defining role in the model. The extreme climatic context in which the igloo developed is represented by an instance of *E3 Condition State*, described as arctic and polar climates. This condition state is associated with the creation event through *P15 was influenced by,* underscoring the formative impact of environmental pressures on architectural form. Additionally, each *E27 Site* is linked to the same condition state via *P44 has condition*, reinforcing the notion that the igloo style is inseparable from the microclimatic realities of the Arctic. The condition state is further classified under the AAT concept of microclimate again referenced through an *E32 Authority Document*.

4.2.2 Constructional, Morphological and Typological Consistencies of the Igloo

The Figure 7 presents a detailed semantic representation of the Igloo Style, modeled as an instance of *E29 Design or Procedure*, into its constituent constructional and morphological techniques. The model foregrounds the procedural knowledge embedded in vernacular Arctic architecture, emphasizing the role of technique as a primary carrier of both functional and environmental adaptation.

At the center of the representation lies the Igloo Style (*E29 Design or Procedure*), which is analytically articulated through a series of subordinate instances of *E29 Design or Procedure*, each representing a distinct construction technique. These techniques are connected to the central style through the property *P46 is composed of*, expressing the idea that the igloo is not a monolithic architectural form, but rather a composite system of interrelated procedural steps. Each subordinate instance of *E29 Design or Procedure* is explicitly classified as a technique through its association with *E55 Type (Technique)* using the property *P2 has type*. This classification establishes technique as a conceptual category within the CIDOC CRM framework, allowing construction processes to be treated as formalized and repeatable.

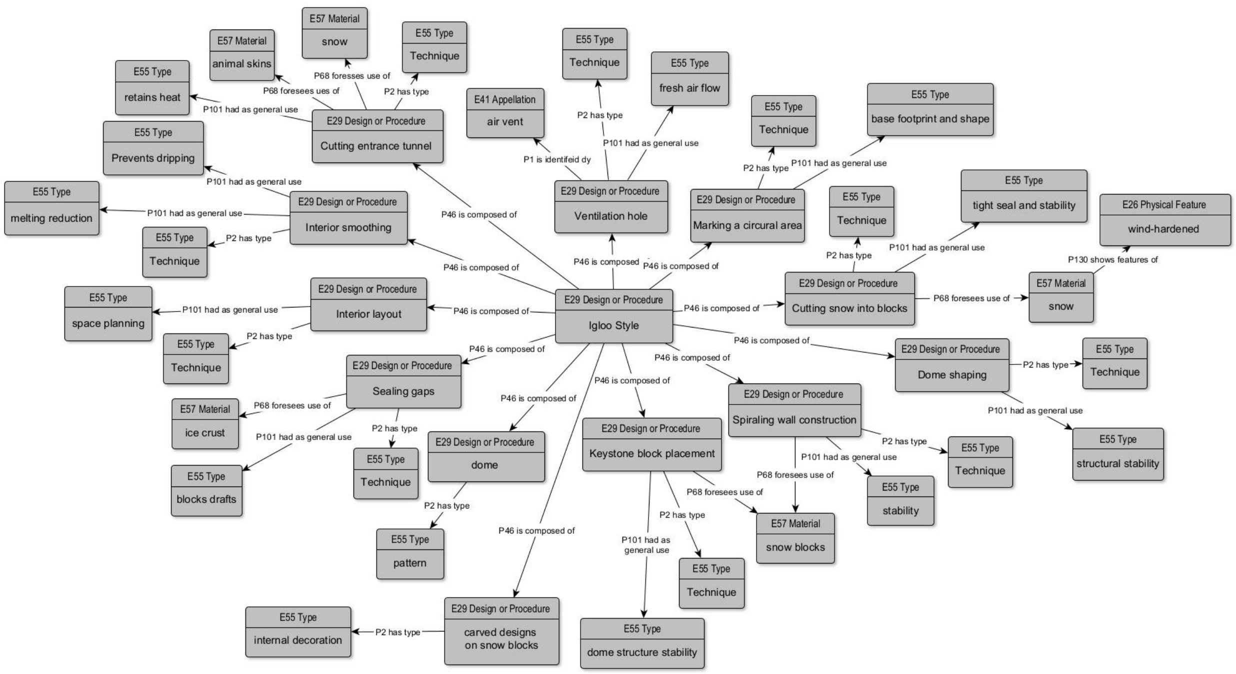

Figure 7: Relating Constructions to Vernacular Architecture Styles - Case study: Igloo

The techniques documented in the model include, among others, cutting snow into blocks, marking a circular base area, spiraling wall construction, dome shaping, keystone block placement, sealing gaps, interior smoothing, interior layout planning, ventilation hole formation, and cutting the entrance tunnel. Each of these techniques contributes to a specific phase of the igloo's construction and collectively defines the architectural logic of the structure. A central feature of the model is the explicit association of each technique with its functional intent. This is achieved through the property *P101 had as general use*, which links techniques to instances of *E55 Type* describing their functional outcomes. These include structural stability, dome stability, tight seal and stability, retention of heat, reduction of melting, prevention of drafts, fresh air flow, space planning, and blocking drafts.

Through this modeling choice, the representation makes explicit the relationship between construction technique and environmental performance. Techniques are not presented merely as steps in a building process, but as targeted responses to specific survival requirements imposed by the Arctic microclimate.

The material dimension of each technique is represented by linking instances of *E29 Design or Procedure* to instances of *E57 Material* through the property *P68 foresees use of*. The primary material identified is snow, including compacted snow blocks, while supplementary materials such as animal skins and ice crust are also incorporated in specific techniques.

To further characterize the material behavior, instances of *E57 Material* are connected to *E26 Physical Feature* via *P130 shows features of*, capturing properties such as wind-hardened surfaces and other material characteristics relevant to structural resistance and insulation. This layered modeling approach enables the articulation of how material properties are anticipated and exploited through specific construction techniques.

Several techniques are directly associated with morphological outcomes, particularly the formation of the dome. The spiraling wall construction and dome shaping techniques, for example, are linked to functional types such as stability and structural stability, while keystone block placement is explicitly associated with dome structure stability. These relationships underscore the sophisticated geometric and structural understanding embedded in vernacular igloo construction. Additionally, the model includes techniques related to surface treatment and interior organization, such as interior smoothing and carved designs on snow blocks, the latter being classified under internal decoration *(E55 Type)*. This demonstrates that vernacular techniques extend beyond pure structural necessity to encompass spatial order and symbolic or aesthetic considerations.

4.2.3 Relating Vernacular Architecture Styles – Drawing in Parallels

This representation addresses the articulation of local variation within the broader conceptualization of the Igloo Style, modeled as an instance of *E29 Design or Procedure*. Rather than depicting the igloo as a uniform and invariant architectural type, the model emphasizes its internal diversity and regional adaptability, highlighting how a shared vernacular tradition manifests through locally specific forms shaped by geographic, environmental, and cultural conditions.

At the center of the model lies the Igloo Style *(E29 Design or Procedure)*, which functions as the common architectural prototype. This prototype is semantically related to several regionally differentiated instances of *E29 Design or Procedure*, each representing a distinct local expression of the igloo tradition. These include, among others, the Greenland Inuit snow house, the Alaskan Inuit snow shelter, and the Inuit snow house of Canada. The relationships between the central style and these regional variants are expressed through the property *P69 has association with*, indicating conceptual and typological connections rather than strict derivation.

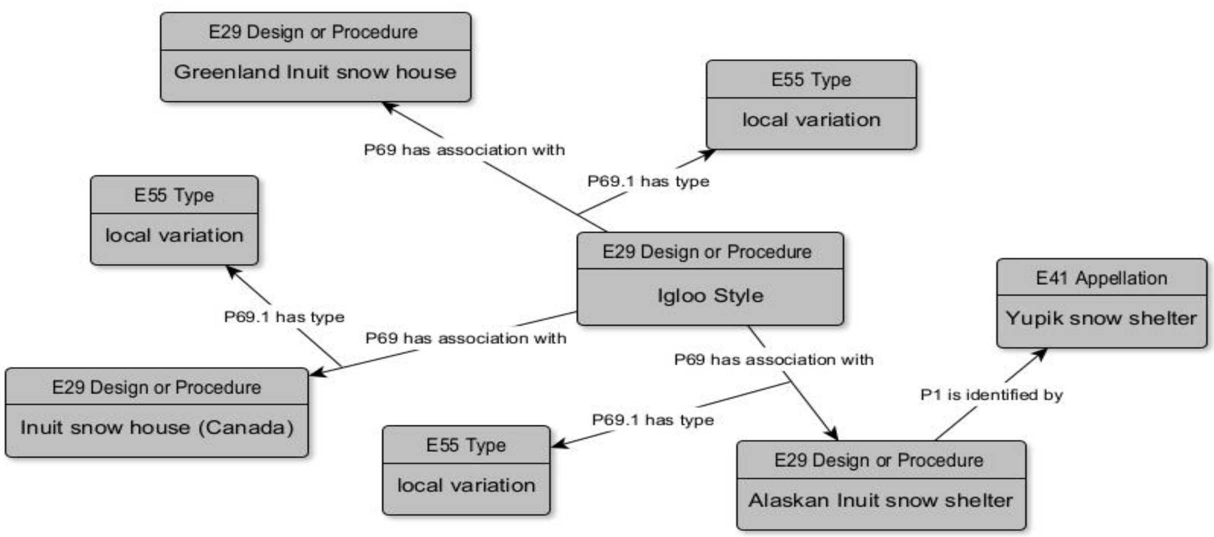

Figure 8: Relating Vernacular Architecture Styles – Case study: Igloo

The nature of each association is further specified using the property of property *P69.1 has type*, which links the association to an instance of *E55 Type* classified as local variation. This qualification explicitly characterizes the relationships as expressions of regional differentiation, allowing the model to capture variation without fragmenting the overall typological coherence of the igloo. In this way, local adaptations are framed not as deviations from an archetype, but as legitimate and context-sensitive realizations of a shared architectural logic.

Each local variation retains the fundamental constructional principles, spatial organization, and environmental responsiveness characteristic of the igloo, while simultaneously reflecting localized factors such as available snow conditions, microclimatic differences, settlement patterns, and social practices. Although these contextual factors are not exhaustively detailed within this specific representation, the semantic structure enables their integration through links to environmental conditions, sites, and cultural groups in complementary models.

Overall, the representation demonstrates how CIDOC CRM supports the documentation of vernacular architecture as a dynamic and plural phenomenon. By modeling local igloo forms as associated instances of *E29 Design or Procedure*, classified explicitly as local variations, the model captures the balance between continuity and diversity that defines vernacular architectural traditions. This approach allows for the systematic comparison of regional forms while preserving the conceptual unity of the igloo as an adaptive Arctic architectural style.

4.2.4 Relating Constructions to Vernacular Architecture Styles

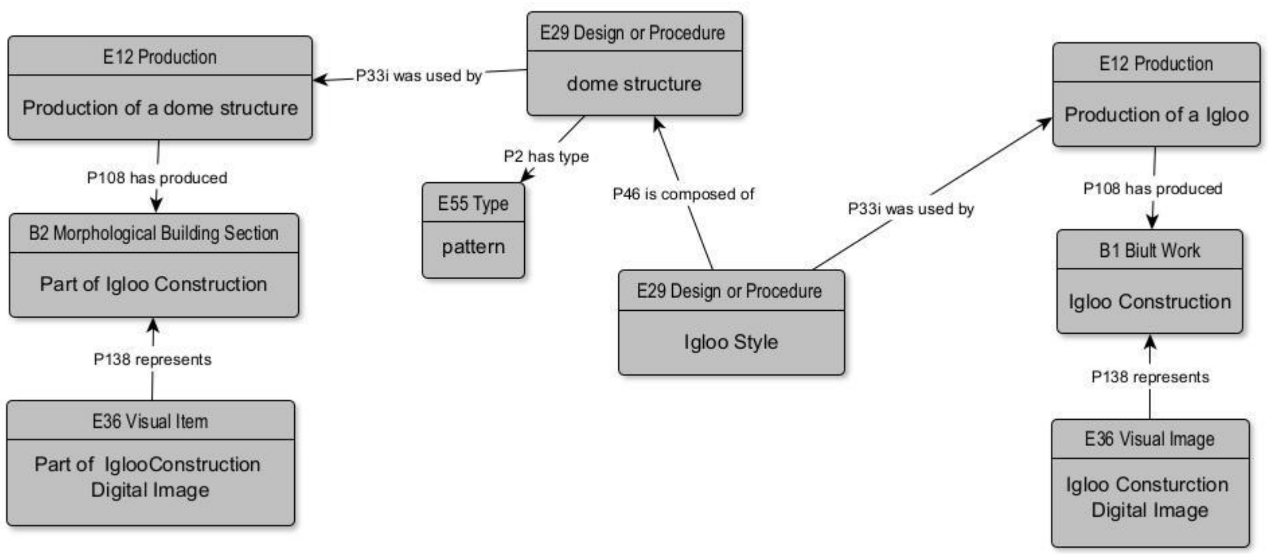

Figure 9: Relating Vernacular Architectural Styles – Case study: Igloo

This representation focuses on the relationship between the Igloo Style, modeled as an instance of *E29 Design or Procedure*, and its realization in concrete architectural constructions, articulated through the concept of Production within the CIDOC CRM framework. The model shifts the analytical focus from abstract architectural knowledge to its material instantiation, demonstrating how vernacular design principles are enacted in specific built works.

At the core of the representation is the Igloo Style *(E29 Design or Procedure)*, which informs and guides the act of construction. The realization of this architectural style is expressed through an instance of *E12 Production*, representing the event during which an igloo is physically constructed. This production event captures the application of vernacular knowledge, techniques, and materials within a specific temporal and spatial context.

The outcome of the production process is modeled as a *B1 Built Work (Igloo Construction)*, a subclass of *E24 Physical Human-Made Thing*, representing a complete and physically realized architectural entity. The relationship between the production event and the built work is articulated through the property P108 has produced, indicating that the igloo construction is the tangible result of the production activity. At the same time, the built work is explicitly linked back to the Igloo Style via the property *P2 has type*, establishing that the constructed igloo conforms to and embodies the principles of the vernacular architectural style.

To allow for a more precise description of architectural form, the model also includes instances of *B2 Morphological Building Section*, which represent discrete morphological components of the igloo, such as sections of the domed envelope or structural segments of the snow-block assembly. These morphological sections are additionally connected to production events, emphasizing that not only the building as a whole, but also its constituent parts, are the result of deliberate construction processes informed by vernacular design procedures. In addition to the physical construction, the model incorporates visual documentation through instances of *E36 Visual Item*. These visual items represent images or visual records depicting either the complete igloo or specific morphological sections. They are linked to the corresponding physical entities via the property *P138 represents*, enabling the semantic association between built works and their visual representations. This linkage supports documentation, analysis, and interpretation without conflating the material object with its representational media.

Overall, the representation demonstrates how the Igloo Style transitions from an abstract body of vernacular knowledge into a tangible architectural artifact through *E12 Production*. By explicitly modeling the production process, the resulting built work, its morphological components, and their visual representations, the model captures the full trajectory from design tradition to material realization. This approach highlights the capacity of CIDOC CRM—augmented by the CRMba extension—to document vernacular architecture not merely as static physical remains, but as the outcome of culturally embedded practices, technical knowledge, and repeated acts of construction within specific environmental contexts.

Chapter 5 Conclusion – Research Results

In this last chapter of the thesis, the conclusions and suggestions for further research will be presented. The aim of this work is to support and contribute to the documentation and management of cultural heritage information and to add to the discussion about the common interests and efforts of digital humanities, computing, and information studies.

5.1 Results and Contributions of the Thesis

This thesis examined the representation of vernacular architecture through a CIDOC CRM-based model focusing on the challenges that arise from its process-oriented character and its strong connection to both environmental and cultural context. Vernacular architecture is approached as the material outcome of living practices, construction techniques and knowledge systems, which are transmitted within local communities. Such a perspective aligns vernacular architecture with the conceptual framework of Intangible Cultural Heritage, as its meaning is shaped by ongoing practices and adaptation rather than fixed forms. The present research shows that style-based documentation models, while effective for formal architectural styles, are not well suited to vernacular architecture. They struggle to capture its local variations, flexible boundaries, and collective character. Therefore, there is a need for modeling approaches that focus on contextual and practice-based dimensions.

Within this framework, CIDOC CRM was explored as a semantic foundation for documenting the complexity of vernacular architecture. The model provides a robust and flexible conceptual structure for representing heterogeneous cultural data through relationships, events, and contextual information. At the same time, CIDOC CRM should not be considered as an automatic solution, as its effective use requires careful modeling decisions and a solid understanding of its principles. Building on this, the proposed CIDOC CRM–based model strengthens the framework by emphasizing on context, practices, materials, and community knowledge. In doing so, it bridges the gap between tangible architectural forms and the intangible cultural processes that sustain them.

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Appendix A: Classes and Properties Hierarchy

E1	CRM Entity						
E2	-	Temporal Entity					
E3	-	-	Condition State				
E4	-	-	Period				
E5	-	-	-	Event			
E7	-	-	-	-	Activity		
E8	-	-	-	-	-	Acquisition	
E96	-	-	-	-	-	-	Purchase
E9	-	-	-	-	-	Move	
E10	-	-	-	-	-	Transfer of Custody	
E11	-	-	-	-	-	Modification	
E12	-	-	-	-	-	-	Production
E79	-	-	-	-	-	-	Part Addition
E80	-	-	-	-	-	-	Part Removal
E13	-	-	-	-	-	Attribute Assignment	
E14	-	-	-	-	-	-	Condition Assessment
E15	-	-	-	-	-	-	Identifier Assignment
E16	-	-	-	-	-	-	Measurement
E17	-	-	-	-	-	-	Type Assignment
E65	-	-	-	-	-	Creation	
E83	-	-	-	-	-	-	Type Creation
E66	-	-	-	-	-	Formation	
E85	-	-	-	-	-	Joining	
E86	-	-	-	-	-	Leaving	
E87	-	-	-	-	-	Curation Activity	
E63	-	-	-	-	Beginning of Existence		
E67	-	-	-	-	-	Birth	
E81	-	-	-	-	-	Transformation	
E12	-	-	-	-	-	Production	
E65	-	-	-	-	-	Creation	
E83	-	-	-	-	-	-	Type Creation
E66	-	-	-	-	-	Formation	
E64	-	-	-	-	End of Existence		
E6	-	-	-	-	-	Destruction	

E68	-	-	-	-	-	Dissolution			
E69	-	-	-	-	-	Death			
E81	-	-	-	-	-	Transformation			
E77	-	Persistent Item							
E70	-	-	Thing						
E72	-	-	-	Legal Object					
E18	-	-	-	-	Physical Thing				
E19	-	-	-	-	-	Physical Object			
E20	-	-	-	-	-	-	Biological Object		
E21	-	-	-	-	-	-	-	Person	
E22	-	-	-	-	-	-	Human-Made Object		
E24	-	-	-	-	-	Physical Human-Made Thing			
E22	-	-	-	-	-	-	Human-Made Object		
E25	-	-	-	-	-	-	Human-Made Feature		
E78	-	-	-	-	-	-	Curated Holding		
E26	-	-	-	-	-	Physical Feature			
E27	-	-	-	-	-	-	Site		
E25	-	-	-	-	-	-	Human-Made Feature		
E90	-	-	-	-	Symbolic Object				
E73	-	-	-	-	-	Information Object			
E29	-	-	-	-	-	Design or Procedure			
E31	-	-	-	-	-	Document			
E32	-	-	-	-	-	-	-	Authority Document	
E33	-	-	-	-	-	-	Linguistic Object		
E34	-	-	-	-	-	-	-	Inscription	
E35	-	-	-	-	-	-	-	Title	
E36	-	-	-	-	-	-	Visual Item		
E37	-	-	-	-	-	-	-	Mark	
E34	-	-	-	-	-	-	-	-	Inscription
E41	-	-	-	-	-	Appellation			
E42	-	-	-	-	-	-	Identifier		
E35	-	-	-	-	-	-	Title		
E95	-	-	-	-	-	-	Spacetime Primitive		
E94	-	-	-	-	-	-	Space Primitive		
E61	-	-	-	-	-	-	Time Primitive		
E71	-	-	-	Human-Made Thing					
E24	-	-	-	-	Physical Human-Made Thing				
E22	-	-	-	-	-	Human-Made Object			

E25	-	-	-	-	-	Human-Made Feature				
E78	-	-	-	-	-	Curated Holding				
E28	-	-	-	-	Conceptual Object					
E90	-	-	-	-	-	Symbolic Object				
E73	-	-	-	-	-	-	Information Object			
E29	-	-	-	-	-	-	-	Design or Procedure		
E31	-	-	-	-	-	-	-	Document		
E32	-	-	-	-	-	-	-	-	Authority Document	
E33	-	-	-	-	-	-	-	Linguistic Object		
E34	-	-	-	-	-	-	-	-	Inscription	
E35	-	-	-	-	-	-	-	-	Title	
E36	-	-	-	-	-	-	-	Visual Item		
E37	-	-	-	-	-	-	-	-	Mark	
E34	-	-	-	-	-	-	-	-	-	Inscription
E41	-	-	-	-	-	-	Appellation			
E42	-	-	-	-	-	-	-	Identifier		
E35	-	-	-	-	-	-	-	Title		
E95	-	-	-	-	-	-	-	Spacetime Primitive		
E94	-	-	-	-	-	-	-	Space Primitive		
E61	-	-	-	-	-	-	-	Time Primitive		
E89	-	-	-	-	-	Propositional Object				
E73	-	-	-	-	-	-	Information Object			
E29	-	-	-	-	-	-	-	Design or Procedure		
E31	-	-	-	-	-	-	-	Document		
E32	-	-	-	-	-	-	-	-	Authority Document	
E33	-	-	-	-	-	-	-	Linguistic Object		
E34	-	-	-	-	-	-	-	-	Inscription	
E35	-	-	-	-	-	-	-	-	Title	
E36	-	-	-	-	-	-	-	Visual Item		
E37	-	-	-	-	-	-	-	-	Mark	
E34	-	-	-	-	-	-	-	-	-	Inscription
E30	-	-	-	-	-	-	Right			
E55	-	-	-	-	-	Type				
E56	-	-	-	-	-	-	Language			
E57	-	-	-	-	-	-	Material			
E58	-	-	-	-	-	-	Measurement Unit			
E98	-	-	-	-	-	-	-	Currency		
E99	-	-	-	-	-	-	Product Type			

E39	-	-	Actor	
E74	-	-	-	Group
E21	-	-	-	Person
E52	-	Time-Span		
E53	-	Place		

Table 2: The CIDOC CRM class hierarchy

Property id	Property Name	Entity –Domain	Entity –Range
P1	is identified by (identifies)	E1 CRM Entity	E41 Appellation
P48	-has preferred identifier (is preferred identifier of)	E1 CRM Entity	E42 Identifier
P102	-has title (is title of)	E71 Human-Made Thing	E35 Title
P168i	-place is defined by (defines place)	E53 Place	E94 Space Primitive
P169i	-spacetime volume is defined by (defines spacetime volume)	E92 Spacetime Volume	E95 Spacetime Primitive
P170i	-time is defined by (defines time)	E52 Time-Span	E61 Time Primitive
P2	has type (is type of)	E1 CRM Entity	E55 Type
P137	-exemplifies (is exemplified by)	E1 CRM Entity	E55 Type
P177	-assigned property type	E13 Attribute Assignment	E55 Type
P3	has note	E1 CRM Entity	E62 String
P79	-beginning is qualified by	E52 Time-Span	E62 String
P80	-end is qualified by	E52 Time-Span	E62 String
P190	-has symbolic content	E90 Symbolic Object	E62 String
P4	has time-span (is time-span of)	E2 Temporal Entity	E52 Time-Span
P5	consists of (forms part of)	E3 Condition State	E3 Condition State
P7	took place at (witnessed)	E4 Period	E53Place
P8	took place on or within (witnessed)	E4 Period	E18 Physical Thing
P12	occurred in the presence of (was present at)	E5 Event	E77 Persistent Item
P111	-added (was added by)	E79 Part Addition	E18 Physical Thing
P113	-removed (was removed by)	E80 Part Removal	E18 Physical Thing
P11	-had participant (participated in)	E5 Event	E39 Actor

Property id	Property Name	Entity –Domain	Entity –Range
P14	--carried out by (performed)	E7 Activity	E39 Actor
P22	---transferred title to (acquired title through)	E8 Acquisition	E39 Actor
P23	---transferred title from (surrendered title through)	E8 Acquisition	E39 Actor
P28	---custody surrendered by (surrendered custody through)	E10 Transfer of Custody	E39 Actor
P29	---custody received by (received custody through)	E10 Transfer of Custody	E39 Actor
P96	--by mother (gave birth)	E67 Birth	E21 Person
P99	--dissolved (was dissolved by)	E68 Dissolution	E74 Group
P143	--joined (was joined by)	E85 Joining	E39 Actor
P144	--joined with (gained member by)	E85 Joining	E74 Group
P145	--separated (left by)	E86 Leaving	E39 Actor
P146	--separated from (lost member by)	E86 Leaving	E74 Group
P151	--was formed from (participated in)	E66 Formation	E74 Group
P16	-used specific object (was used for)	E7 Activity	E70 Thing
P33	--used specific technique (was used by)	E7 Activity	E29 Design or Procedure
P111	--added (was added by)	E79 Part Addition	E18 Physical Thing
P142	--used constituent (was used in)	E15 Identifier Assignment	E90 Symbolic Object
P25	-moved (moved by)	E9 Move	E19 Physical Object
P31	-has modified (was modified by)	E11 Modification	E18 Physical Thing
P108	--has produced (was produced by)	E12 Production	E24 Physical Human-Made Thing
P110	--augmented (was augmented by)	E79 Part Addition	E24 Physical Human-Made Thing
P112	--diminished (was diminished by)	E80 Part Removal	E24 Physical Human-Made Thing

Property id	Property Name	Entity –Domain	Entity –Range
P92	-brought into existence (was brought into existence by)	E63 Beginning of Existence	E77 Persistent Item
P94	--has created (was created by)	E65 Creation	E28 Conceptual Object
P135	---created type (was created by)	E83 Type Creation	E55 Type
P95	--has formed (was formed by)	E66 Formation	E74 Group
P98	--brought into life (was born)	E67 Birth	E21 Person
P108	--has produced (was produced by)	E12 Production	E24 Physical Human-Made Thing
P123	--resulted in (resulted from)	E81 Transformation	E77 Persistent Item
P93	-took out of existence (was taken out of existence by)	E64 End of Existence	E77 Persistent Item
P13	--destroyed (was destroyed by)	E6 Destruction	E18 Physical Thing
P99	--dissolved (was dissolved by)	E68 Dissolution	E74 Group
P100	--was death of (died in)	E69 Death	E21 Person
P124	--transformed (was transformed by)	E81 Transformation	E77 Persistent Item
P15	was influenced by (influenced)	E7 Activity	E1 CRM Entity
P16	-used specific object (was used for)	E7 Activity	E70 Thing
P33	--used specific technique (was used by)	E11 Modification	E29 Design or Procedure
P111	--added (was added by)	E79 Part Addition	E18 Physical Thing
P142	--used constituent (was used in)	E15 Identifier Assignment	E90 Symbolic Object
P17	-was motivated by (motivated)	E7 Activity	E1 CRM Entity
P134	-continued (was continued by)	E7 Activity	E7 Activity
P136	-was based on (supported type creation)	E83 Type Creation	E1 CRM Entity
P19	was intended use of (was made for)	E7 Activity	E71 Human-Made Thing

Property id	Property Name	Entity –Domain	Entity –Range
P20	had specific purpose (was purpose of)	E7 Activity	E5 Event
P21	had general purpose (was purpose of)	E7 Activity	E55 Type
P24	transferred title of (changed ownership through)	E8 Acquisition	E18 Physical Thing
P26	moved to (was destination of)	E9 Move	E53 Place
P27	moved from (was origin of)	E9 Move	E53 Place
P30	transferred custody of (custody transferred through)	E10 Transfer of Custody	E18 Physical Thing
P43	has dimension (is dimension of)	E70 Thing	E54 Dimension
P44	has condition (is condition of)	E18 Physical Thing	E3 Condition State
P45	consists of (is incorporated in)	E18 Physical Thing	E57 Material
P49	has former or current keeper (is former or current keeper of)	E18 Physical Thing	E39 Actor
P50	-has current keeper (is current keeper of)	E18 Physical Thing	E39 Actor
P109	-has current or former curator (is current or former curator of)	E78 Curated Holding	E39 Actor
P51	has former or current owner (is former or current owner of)	E18 Physical Thing	E39 Actor
P52	-has current owner (is current owner of)	E18 Physical Thing	E39 Actor
P53	has former or current location (is former or current location of)	E18 Physical Thing	E53 Place
P55	-has current location (currently holds)	E19 Physical Object	E53 Place
P156	-occupies (is occupied by)	E18 Physical Thing	E53 Place
P54	has current permanent location (is current permanent location of)	E19 Physical Object	E53 Place
P57	has number of parts	E19 Physical Object	E60 Number

Property id	Property Name	Entity –Domain	Entity –Range
P59	has section (is located on or within)	E18 Physical Thing	E53 Place
P62	depicts (is depicted by)	E24 Physical Human-Made Thing	E1 CRM Entity
P67	refers to (is referred to by)	E89 Propositional Object	E1 CRM Entity
P68	-foresees use of (use foreseen by)	E29 Design or Procedure	E57 Material
P70	-documents (is documented in)	E31 Document	E1 CRM Entity
P71	-lists (is listed in)	E32 Authority Document	E1 CRM Entity
P129	-is about (is subject of)	E89 Propositional Object	E1 CRM Entity
P138	-represents (has representation)	E36 Visual Item	E1CRM Entity
P69	has association with (is associated with)	E29Design or Procedure	E29 Design or Procedure
P72	has language (is language of)	E33 Linguistic Object	E56 Language
P74	has current or former residence (is current or former residence of)	E39 Actor	E53 Place
P75	possesses (is possessed by)	E39 Actor	E30 Right
P76	has contact point (provides access to)	E39 Actor	E41 Appellation
P81	ongoing throughout	E52 Time-Span	E61 Time Primitive
P82	at some time within	E52 Time-Span	E61 Time Primitive
P86	falls within (contains)	E52 Time-Span	E52 Time-Span
P89	falls within (contains)	E53 Place	E53 Place
P90	has value	E54 Dimension	E60 Number
P91	has unit (is unit of)	E54 Dimension	E58 Measurement Unit
P180	-has currency	E97 Monetary Amount	E98 Currency
P97	from father (was father for)	E67 Birth	E21 Person
P101	had as general use (was use of)	E70 Thing	E55 Type
P103	was intended for (was intention of)	E71 Human-Made Thing	E55 Type
P104	is subject to (applies to)	E72 Legal Object	E30 Right
P105	right held by (has right on)	E72 Legal Object	E39 Actor
P52	-has current owner (is current owner of)	E18 Physical Thing	E39 Actor

Property id	Property Name	Entity –Domain	Entity –Range
P106	is composed of (forms part of)	E90 Symbolic Object	E90 Symbolic Object
P165	-incorporates (is incorporated in)	E73 Information Object	E90 Symbolic Object
P107	has current or former member (is current or former member of)	E74 Group	E39 Actor
P121	overlaps with	E53 Place	E53 Place
P122	borders with	E53 Place	E53 Place
P125	used object of type (was type of object used in)	E7 Activity	E55 Type
P32	-used general technique (was technique of)	E7 Activity	E55 Type
P126	employed (was employed in)	E11 Modification	E57 Material
P127	has broader term (has narrower term)	E55 Type	E55 Type
P130	shows features of (features are also found on)	E70 Thing	E70 Thing
P73i	-is translation of	E33 Linguistic Object	E33 Linguistic Object
P128	-carries (is carried by)	E18 Physical Thing	E90 Symbolic Object
P65	--shows visual item (is shown by)	E24 Physical Human-Made Thing	E36 Visual Item
P132	spatiotemporally overlaps with	E92 Spacetime Volume	E92 Spacetime Volume
P10	-falls within (contains)	E92 Spacetime Volume	E92 Spacetime Volume
P166	--was a presence of (had presence)	E93 Presence	E92 Spacetime Volume
P46	is composed of (forms part of)	E18 Physical Thing	E18 Physical Thing
P56	-bears feature (is found on)	E19 Physical Object	E26 Physical Feature
P133	is separated from	E92 Spacetime Volume	E92 Spacetime Volume
P139	has alternative form	E41 Appellation	E41 Appellation
P140	assigned attribute to (was attributed by)	E13 Attribute Assignment	E1 CRM Entity
P34	-concerned (was assessed by)	E14 Condition Assessment	E18 Physical Thing
P39	-measured (was measured by)	E16 Measurement	E1 CRM Entity
P41	-classified (was classified by)	E17 Type Assignment	E1 CRM Entity

Property id	Property Name	Entity –Domain	Entity –Range
P141	assigned (was assigned by)	E13 Attribute Assignement	E1 CRM Entity
P35	-has identified (identified by)	E14 Condition Assessment	E3 Condition State
P37	-assigned (was assigned by)	E15 Identifier Assignement	E42 Identifier
P38	-deassigned (was deassigned by)	E15 Identifier Assignement	E42 Identifier
P40	-observed dimension (was observed in)	E16 Measurement	E54 Dimension
P42	-assigned (was assigned by)	E17 Type Assignment	E55 Type
P147	curated (was curated by)	E87 Curation Activity	E78 Curated Holding
P148	has component (is component of)	E89 Propositional Object	E89 Propositional Object
P150	defines typical parts of (defines typical wholes for)	E55 Type	E55 Type
P152	has parent (is parent of)	E21 Person	E21 Person
P157	is at rest relative to (provides reference space for)	E53 Place	E18 Physical Thing
P59i	-is located on or within	E53Place	E18PhysicalThing
P156i	-is occupied by	E53 Place	E18 Physical Thing
P160	has temporal projection	E92 Spacetime Volume	E52 Time-Span
P164	-is temporally specified by (temporally specifies)	E93 Presence	E52 Time-Span
P161	has spatial projection	E92 Spacetime Volume	E53 Place
P167	was within (includes)	E93 Presence	E53 Place
P171	at some place within	E53 Place	E94 Space Primitive
P172	Contains	E53 Place	E94 Space Primitive
P173	starts before or with the end of (ends after or with the start of)	E2 Temporal Entity	E2 Temporal Entity
P174	-starts before the end of (ends after the start of)	E2 Temporal Entity	E2 Temporal Entity
P184	--ends before or with the end of (ends with or after the end of)	E2 Temporal Entity	E2 Temporal Entity

Property id	Property Name	Entity –Domain	Entity –Range
P185	---ends before the end of (ends after the end of)	E2 Temporal Entity	E2 Temporal Entity
P182	----ends before or at the start of (starts after or with the end of)	E2TemporalEntity	E2TemporalEntity
P175	--starts before or with the start of (starts after or with the start of)	E2 Temporal Entity	E2 Temporal Entity
P176	---starts before the start of (starts after the start of)	E2 Temporal Entity	E2 Temporal Entity
P134i	----was continued by	E7 Activity	E7 Activity
P182	----ends before or at the start of (starts after or with the end of)	E2 Temporal Entity	E2 Temporal Entity
P183	-----ends before the start of (starts after the end of)	E2 Temporal Entity	E2 Temporal Entity
P179	had sales price (was sales price of)	E96 Purchase	E97 Monetary Amount
P186	produced thing of product type (is produced by)	E12 Production	E99 Product Type
P187	has production plan (is production plan for)	E99 Product Type	E29 Design or Procedure
P188	requires production tool (is production tool for)	E99 Product Type	E19 Physical Object
P189	Approximates	E53 Place	E53 Place
P191	had duration (was duration of)	E52 Time-Span	E54 Dimension
P195	was a presence of (had presence)	E93 Presence	E18 Physical Thing
P196	defines (is defined by)	E18 Physical Thing	E92 Spacetime Volume
P197	covered parts of (was partially covered by)	E93 Presence	E53 Place
P198	holds or supports (is held or supported by)	E18 Physical Thing	E18 Physical Thing

Table 3: The CIDOC CRM property hierarchy

Property id	Property Name	Property – Domain	Entity – Range
P3.1	has type	E1 CRM Entity. P3 has note: E62 String	E55 Type
P14.1	in the role of	E7 Activity. P14 carried out by (performed): E39 Actor	E55 Type
P16.1	mode of use	E7 Activity. P16 used specific object (was used for): E70 Thing	E55 Type
P19.1	mode of use	E7 Activity. P19 was intended use of (was made of): E71 Human-Made Thing	E55 Type
P62.1	mode of depiction	E24 Physical Human-Made Thing. P62 depicts (is depicted by): E1 CRM Entity	E55 Type
P67.1	has type	E89 Propositional Object. P67 refers to (is referred to by): E1 CRM Entity	E55 Type
P138.1	-mode of representation	E36 Visual Item. P138 represents (has representation): E1 CRM Entity	E55 Type
P69.1	has type	E29 Design or Procedure. P69 has association with (is associated with): E29 Design or Procedure	E55 Type
P102.1	has type	E71 Human-Made Thing. P120 has title (is title of): E35 Title	E55 Type
P107.1	kind of member	E74 Group. P107 has current or former member (is current or former member of): E39 Actor	E55 Type
P136.1	in the taxonomic role	E83 Type Creation. P136 was based on (supported type creation): E1 CRM Entity	E55 Type
P130.1	kind of similarity	E70 Thing. E130 shows features of (features are also found on): E70 Thing	E55 Type
P137.1	in the taxonomic role	E1 CRM Entity. P137 exemplifies (is exemplified by): E55 Type	E55 Type
P139.1	has type	E41 Appellation. P139 has alternative form (is alternative form of): E41 Appellation	E55 Type
P144.1	kind of member	E85 Joining. P144 joined with (gained member of): E 74 Group	E55 Type
P189.1	has type	E53 Place. P189 approximates (is approximated by): E53 Place	E55 Type

Table 4: The CIDOC CRM property of property hierarchy

Appendix B: Classes and Properties used in the Vernacular Architecture Model

Classes	Use in the data model
E3 Condition State	To describe the state of climate's condition
E7 Activity	To describe the origins and the culture
E12 Production	To describe the production of a building using vernacular architecture
E26 Physical Feature	To describe physical features that the climate of a place may have
E29 Design or Procedure	To describe vernacular architecture's style and the technique used to construct a structure
E32 Authority Document	To define the thesaurus/controlled vocabulary from which the specific term-code was derived
E36 Visual Item	To describe a picture that depicts a vernacular architecture structure
E41 Appellation	To describe the name of a vernacular architecture structure
E52 Time-Span	To describe the time was built the vernacular architecture structure
E53 Place	To describe the place was located the vernacular architecture structure
E55 Type	To classify instances across most classes in the model
E57 Material	To describe the materials used in the construction techniques of the vernacular architecture structure
E65 Creation	To describe the instance of the very vernacular architecture structure's creation
E74 Group	To describe the people from whom it came the vernacular architecture structure

Table 5: CIDOC CRM classes used in the data model

Property id	Property Name	Entity –Domain	Entity –Range
P71	lists	E32 Authority Document	E55 Type
P2	has type	E29 Design or Procedure/ E7 Activity/ E55 Type	E55 Type
P1	is identified by	E29 Design or Procedure	E41 Appellation
P8	took place in or within	E65 Creation	E27 Site
P15	was influenced by	E65 Creation	E7 Activity
P44	has condition	E27 Site	E3 Condition State
P53	has former or current location	E27 Site	E53 Place
P94	has created	E65 Creation	E29 Design or Procedure
P4	has time-span	E65 Creation	E52 Time-Span
P11	had participant	E65 Creation	E74 Group
P14	carried out by	E7 Activity	E74 Group
P103	was intended for	E29 Design or Procedure	E55 Type
P101	had as general use	E29 Design or Procedure	E55 Type
P139	has alternative form	E41 Appellation	E41 Appellation
P69	has association with (P69.1 has type)	E29 Design or Procedure	E29 Design or Procedure
P46	is composed of	E29 Design or Procedure	E29 Design or Procedure
P68	foresees use of	E29 Design or Procedure	E57 Material
P130	shows features of	E57 Material	E26 Physical Feature

Table 6: CIDOC CRM properties used in the data model