Sociomaterial design of coordination in knowledge sharing: A heritage KMS reference architecture

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Sociomaterial design of coordination in knowledge sharing: A heritage KMS reference architecture

Doctoral thesis
To obtain the title of Doctor
At Pontificia Universidad Javeriana

By

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Given in Bogotá, Colombia
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This thesis is dedicated to Andrea and Juanjo, whose love and support made my dream a reality.

To my lovely Mother, Elsa, whose love was my motivation.
PREFACE & ACKNOWLEDGEMENTS

We are living in a world that evolves so fast, partly due to technology development which sometimes does not care for humanity issues but sometimes help us to support them. Conserving the human identity through protecting the cultural and material heritage objects is one of those relevant issues. All humans are co-responsible of this task, irrespective of the territory on which the objects are located. Many researchers around the world are working on how to avoid deterioration or disappearance of any item of the cultural heritage, but this goal requires high levels knowledge coordination. Currently, there is a research gap regarding to the techno-centric and deterministic strategies for designing coordination based on the information-processing view, versus human behavior when using coordination mechanisms in practice. Additionally, there is a lack of understanding about how that gap affects the knowledge sharing process. The main barrier of this sociotechnical approach is that its coordination design philosophy overlooks the social dynamics of coordination, the material agencies of the mechanisms and the contextual dimensions in which any of them unfolds for sharing knowledge.

In the last decade, scholars in the IS discipline have started to re-conceptualize relations between human and material agencies, examining how actions and relations between them are materially constituted in practice, and thus sociomaterial in nature. The sociomaterial perspective grounds on the fact that knowledge is not attributable to a single material, such as a specific technology or infrastructure, but to interacting agencies in everyday life. Sociomateriality allows to overcome the dichotomy between dependencies and coordination mechanisms by understanding coordination as the imbrication of people ability to form and realize coordination goals and the material capacity of the mechanisms to act on their own, apart from human intervention. However, sociomateriality is mainly focused on theoretical and philosophical debates and there is a lack of applicable knowledge to guide the design of new IT artifacts from the sociomaterial thinking.

In this research, we argued and validated that designing knowledge management systems (KMS) from sociomaterial tenets has the potential to improve coordination in knowledge sharing activities. By following a design science research (DSR) strategy with three iterations of rigor, relevance and design/evaluation cycles, we conducted a sociomaterial design process materialized in a reference architecture for KMS. In doing so, we identify design requirements, formulate sociomaterial design guidelines with their corresponding implementation guidelines, and instantiate and evaluate these through a prototypical instantiation of a KMS. The capability of this design approach has been evolved from and demonstrated in an international and interorganizational KS network in the heritage domain. We demonstrate how technology designers can use sociomateriality as a design lens enabling them to further create IT-based coordination mechanisms and we show the value of considering SM design to advance in overcoming coordination issues for sharing knowledge. In this research we have postulated an integral perspective of sociomaterial design that moves forward the theoretical and philosophical knowledge of sociomateriality and the empirical settings when investigating coordination for knowledge sharing processes. These artefacts provide a conceptual framework and a design framework for IS scholars, practitioners and designers, about the sociomaterial design of information systems for the study of coordination in the heritage work.
This doctoral research has been supported by different organizations, professors, colleagues and friends who supported me towards the completion of my PhD research and to which I am very grateful. I would like to thank my promotor, Professor Rafael Gonzalez, for providing me with the opportunity to conduct this research. His valuable comments not only helped me to guide my dissertation research, but also to set my priorities always thinking of the future. He challenged me to remain focused and remain determined to complete this work. I do appreciate the support, patience and priceless guidance throughout the project. I am so grateful to him. Special thanks to Professor Alejandra Magana from Purdue University for allowing me to explore other research opportunities and comprehend the value of collaboration when doing research. Her support during my research stay at Purdue University helped me to move my thoughts forward and to speed up my process by offering my lots of inspiration. During the preparation of my defense, Professor Carsten Østerlund provided me several and meaningful ideas and suggestions to enhance my dissertation, allowing me to align my discourse, thoughts and insights in philosophical terms.

During my research period, I was lucky to meet wonderful research participants who were always willing to share their knowledge about the heritage domain. My sincere gratitude goes to Professors Lina Beltran and Carlos Nieto from the Architecture Faculty at Javeriana University, who were always available for conversations and interviews regarding my research, but also about families and personal experiences. I would like to thank other architects from Javeriana University that helped me during the validation process: Juan, Gloria, Maria Teresa, Estela, Jenny, Cecilia y Laura.

I also appreciate funding from Colciencias during my whole research, as well as institutional support of Javeriana University through Carlos Parra and Silene Alvarado. Many thanks to RedPHI members for being always available for information requests.

The success of this thesis would not have been possible without the support and continuous participation of relevant colleagues and friends in Colombia: Jorge Rueda, Luis Vilches, Juan Pablo Pájaro for their valuable support and for sharing knowledge and experiences that made my research journey valuable. Also, several friends from Purdue University who motivated me to move the barriers of my research and supported me in personal and professional streams: Camilo Vieira, Juan David, Ortega, Joselyn Walsh, Jenny Quintana, Genisson Coutinho, Tugba Yuksel, Hayden Fennell, John Mendoza. Special thanks to Sandra and Johan for their hospitality and support during my stay in United States.

Last, but certainly not least, I would like to thank my dear wife, Andrea Gonzalez; to my adorable son, Juan Jose Nova; to my lovely mother, Elsa Arevalo; to my brother, Dario Nova; and other family members for raising me to be a better person and for your love and support.
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1INTRODUCTION
Contemporary knowledge management systems (KMS) involve the active participation of a wide range of stakeholders in cross-disciplinary and temporary project-based settings. However, currently there are two main challenges in KMS design processes. On the one hand, organizations often compel team members to use a fixed set of tools to share project information, but on the other hand, stakeholders are sharing knowledge through artifact ecosystems consisting of multiple and distinct technologies configured and reconfigured dynamically according to contextual changes, which can be seen as a sociomaterial practice (Orlikowski, 2007). The first option is based on the Information-processing view (IP) of coordination (Malone & Crowston, 1994) which implies identifying and matching interdependencies between activities with coordination mechanisms (CMs), stressing the importance of prediction of coordination needs (Faraj & Xiao, 2006; P. A. Jarzabkowski, Lê, & Feldman, 2011; Okhuysen & Bechky, 2009) and the use of structured and shared cognitive models (Constantinides & Barrett, 2012). But this option seems hard to sustain because of the 70 percent of failures in IS, including KMS, within two years of implementation (Kautz & Cecez-Kecmanovic, 2013) but also due to their limited potential to address dynamic, emergent and situated coordination practices that are difficult to be reduced to patterns as input for a predictive model. In addition, coordination from the information-processing (IP) view does not account for some of the novel technological phenomena (Orlikowski, 2009) such as ubiquitous and pervasive infrastructure (Jarrahi, Nelson, & Thomson, 2017) and social phenomena like heterogeneity (Cummings, Kiesler, Bosagh Zadeh, & Balakrishnan, 2013; Lertpittayapoom, Nongkran, 2005), which are becoming more common in knowledge-sharing practices.

The second option attempts to overcome these pitfalls. Sociomateriality has contributed to understanding the role of technology in today’s organizational practice (Leonardi, 2013) and the use of this concept in IS and management and organization studies has been significant – between 2009 and 2018 over 337 journal articles were published that referred to sociomateriality¹, and most of them referred to Orlikowski and Scott’s work (Feldman & Orlikowski, 2011; Orlikowski, 2007, 2009; Scott & Orlikowski, 2008). Despite the growing support that sociomateriality is receiving currently, it seems the debate is mainly focused on which metaphor could represent better the sociomaterial approach and what philosophical roots it enacts (Cecez-Kecmanovic, Galliers, Henfridsson, Newell, & Vidgen, 2014; Mueller, Renken, & van Den Heuvel, 2016). In this regard, the sociomaterial orientation is extremely theoretical, philosophical in nature and applicable just as a conceptual lens because the IS discipline lacks empirical guidance on how to operationalize the concept (Leonardi, 2013; Scott & Orlikowski, 2013). Consequently, sociomateriality is especially difficult to apply in the design context because there is a lack of guidelines to design artifacts based on sociomaterial thinking (Constantinides & Barrett, 2012; Contractor, Monge, & Leonardi, 2011; Seeber, 2013). In this research, we respond to calls to investigate how an IS should be designed using a sociomaterial approach (Bjørn & Østerlund, 2014) by proposing a reference architecture composed of a set of sociomaterial design guidelines and implementation guidelines for KMS that improve coordination in knowledge sharing practices.

¹ Data from WOS, June 14th 2018
The reference architecture and its corresponding instantiation in a knowledge Management System - KMS (as design artifacts) were built by conducting a design science research (DSR) study to develop a reference architecture composed of four design guidelines that concern a class of information systems, that is, the product of design (Iivari, 2007; Walls, Widmeyer, & El Sawy, 1992). We follow an abductive research method in which insights from a problem-solving cycle are related with concepts from a research cycle and concepts from research cycle are iteratively validated through evidence from a problem-solving cycle (Mathiassen, Chiasson, & Germonprez, 2012). The architecture was validated through multiple rounds of designing, demonstrating and evaluating a prototypical implementation of a KMS.

This doctoral thesis is an improvement research (Gregor & Hevner, 2014) since it contends with a known application context for which useful solution artifacts either do not exist or are clearly suboptimal. Our research domain is the Iberoamerican Historical Heritage Network – RedPHI, which is specialized in material architectural heritage management (Red PHI, 2018). RedPHI is an international and interorganizational network of 46 universities of seven countries aiming to share specialized knowledge between expert and non-expert people supporting decision-making in public and private institutions, which are interested in getting involved in activities such as rehabilitation, conservation or protection of material and historical heritage.

In this research, we aimed to (a) propose design guidelines that lead the KMS designing process, (b) evaluate and revise these design guidelines through the implementation, demonstration and evaluation of a purposeful IT artifact and (c) extend our limited understanding of using sociomateriality as an appropriate lens to design KMS that support coordination in knowledge sharing activities. While our DSR study is in the substantive context of knowledge sharing between heritage projects in the RedPHI domain, and we thus develop a reference architecture for a specific class of information systems named KMS (Alavi & Leidner, 2001); we also contribute to our understanding of how a broader class of KMS might be designed by following the sociomaterial tenets.

1.1 The role of coordination in knowledge sharing networks

Even though the sharing of knowledge across and within firms has emerged as an underlying theme in strategy and organization research, the literature recognizes that ICTs may influence the effectiveness of interorganizational knowledge sharing (Lertpittayapoom, Nongkran, 2005). By definition, interorganizational knowledge sharing involves at least two organizations performing independent activities but collaborating, at some time, with others to develop a common task, and so it is important to identify the interactive dynamics between these organizations (Easterby-Smith, Lyles, & Tsang, 2008). Dynamic interactions are related with the set of coordination mechanisms that people and organizations use to share knowledge between firms.

The coordination of the interorganizational relationship refers to the context in which knowledge sharing takes place, and the coordination mechanisms, which emerge within that context. Some argue that the more mechanisms supporting interactions between individuals and groups of the organizations are used, the more likely will be the transfer of multiple types of knowledge (Easterby-Smith et al., 2008). However, empirical studies suggest that coordination issues for
sharing knowledge are not a matter of quantity of mechanisms but a proper choice according to contextual dimensions (Nova & Gonzalez, 2016a, 2016b). Coordination (Bdeir, Hossain, & Crawford, 2013), contextual dimensions (Zorina & Avison, 2011) and heterogeneity (Cummings et al., 2013) play a crucial role in the way that interorganizational knowledge sharing works and changes.

The knowledge sharing process between project teams is complex due to various prerequisites/conditions and contextual issues surrounding it. Sharing knowledge is a difficult type of process that requires coordinative practices between two or more individuals or functional units who are separated and differentiated by structural, cultural, disciplinary and organizational boundaries (Anderson, 2016; Cummings & Kiesler, 2008; Espinosa, 2009; Espinosa, Cummings, & Pickering, 2012; A. Malhotra & Majchrzak, 2014). For instance, knowledge work in a cultural heritage network involves specialists embedded in different disciplines, ontological and epistemological views, work methodologies, technical perspectives and, thus, requires the reconciliation and transformation of current practices to get a common understanding. Accordingly, coordination theory offers a productive lens for studying these challenges in interorganizational and multidisciplinary projects and for advancing theory as well.

In knowledge sharing literature, often coordination mechanisms have been seen as a transport channel where something produced (eg. knowledge) by a “producer’ activity is moved to one “consumer” activity (Alavi & Leidner, 2001; Szulanski, 1996). Coordination traditionally rest on shared models that were formulated in the era in which manufacturing and production work was the dominant organizational form (Okhuysen & Bechky, 2009). However, coordination for knowledge sharing, far from being considered as a deterministic or instrumental process, has been understood as a social activity. A social perspective applied to the context of knowledge management helps identify and analyze knowledge sharing in organizations (Retzer, Yoong, & Hooper, 2012). The social concept of coordination enacts an ongoing and relational practice performed by different people and a set of coordination mechanisms interacting with each other in order to share knowledge. Nevertheless, coordination mechanisms act as non-human agencies (Latour, 2005) performing actions as a human actor (e.g. in some cases certain technologies are considered as expert sources of knowledge). Similarly, people “use” technologies in much the same ways that they “use” coworkers and friends (Su, Huang, & Contractor, 2010).

1.2 Challenges of designing ICT-based coordination

Coordinating experts to find an effective knowledge sharing space has been one of the key issues in organization science (Malone and Crowston, 1994; Mintzberg, 1983). Coordination is based on characteristics of people and their relationships, such as organizational design and heterogeneity, but also on what tools they use to share individual and groups ideas, how they coordinate those tools as well as the space-temporal settings in which they are living right now. Nowadays, coordination is intelligent, so that technology is no longer another tool in the box but a way to keep together different personal ecosystems that become aligned to solve a domain issue.

A literature review and a case study suggest that heterogeneity in knowledge sharing networks, derived from team member differences in knowledge, expertise, or experience, can increase group creativity, but also can make coordination highly complex (Cummings et al., 2013; Nova &
The knowledge sharing process involves a wide range of heterogeneous stakeholders in cross-disciplinary and temporary project-based settings. Heterogeneity in people (Cummings & Kiesler, 2008), technology (Contractor et al., 2011), contexts (Bechky, 2003), interests (Carlile, 2002), disciplines, expertise (Cummings & Kiesler, 2014), and ontological and epistemological perspectives (Faraj & Xiao, 2006), determine how coordination is enacted dynamically in practice.

Note that all of these aspects represent a wide variety of factors that have an impact on the different coordination choices. A variation in one interdependency, due to changes in heterogeneous factors, would be better matched with a variety of coordination activities and mechanisms, and so the match would take into account the impact of social, material and temporal contexts. Moreover, coordination mechanisms should become more flexible and sophisticated to cope with task uncertainty (variety and unpredictability) in the context, the technology or the strategy. Flexibility means that coordination for knowledge sharing practices should be designed in practice as an ongoing and contextualized interaction between action possibilities perceived from ICTs and material properties embedded in them.

The key issue of coordination is that it is often designed and implemented from a management view in which organizational process, standards, software policies, or headquarters decisions attempt to predict and control how people share knowledge with each other, trying to govern human perceptions of what technology can afford coordination in collaboration activities. The well-known theory of coordination, developed by Malone and colleagues (Malone & Crowston, 1994; Malone et al., 1999) and based on the Information Processing view – IP (Galbraith, 1974), proposes that a deeper and exhaustive identification and characterization of task interdependencies in the application domain can be reached so that it is possible to enlist a set of coordination mechanisms – CMs, enacting a coordination treatment that eventually could match knowledge sharing needs. This logic of pre-determination, prediction and pre-specification of routines, rules, procedures and mechanisms to coordinate knowledge work (Y. Malhotra, 2001, 2004) has traditionally oriented the design of information systems such as KMS (Alavi & Leidner, 2001). But also, it has been criticized because literature and empirical research have demonstrated that coordination, far from being a static phenomenon, is highly dynamic, emergent, contextualized and non-patterned (Faraj & Xiao, 2006; P. A. Jarzabkowski et al., 2011; Okhuysen & Bechky, 2009).

This static perspective of coordination has been challenged in some ways. First, any change in just one heterogeneous factor could create a new requirement that may have not been fully contemplated or understood. Second, the wide variety of ICTs for coordination afford people with many possibilities to use, switch, toggle, substitute and combine multiple and different CMs according to contextual dimensions of the ongoing coordination practices. Thus, novel coordination treatments can be developed as people perceive a new affordance or constraint from the CM being used so that enlisting the overall coordination treatments would always be ongoing. Third, coordination occurs both at an individual level and at a group level. Personal artifact ecosystems are coordinated individually to fit individual interests but when a knowledge need occurs, different ecosystems must be coordinated with each other to meet knowledge
requirements. Even though organizations make mandatory use of a specific CM, people continue using and coordinating their ecosystems as they prefer to the extent of their possibilities.

Ultimately, bureaucratic settings of coordination design need to be replaced by ad hoc, personalized and collaborative coordination performed in practice, sharing design value with users. This implies overcoming traditional coordination design approaches that enact epistemologies of determinism, exogeneity, and independency as it is assumed that technology is a determinant factor in knowledge work (Halawi, McCarthy, & Aronson, 2017; Sajeva, 2010) and operates without human intervention as intended and designed across time and place (Orlikowski, 2007, 2009; Scott & Orlikowski, 2008). In this sense, disappointing results of knowledge sharing artifacts are due to the fact that designers traditionally analyze just digital or physical materials, but neglect the underlying social relations surrounding knowledge sharing processes (Ciborra, 1999; Newell, Robertson, Scarbrough, & Swan, 2009); thus ignoring the social dynamics and contextual dimensions in which any IS project unfolds (Doherty, Ashurst, & Peppard, 2012).

1.3 Enabling coordination design through sociomateriality

Recent research about coordination is less concerned with predictive coordination design for optimum performance, and more on exploring coordination as it happens in practice (Okhuysen & Bechky, 2009). In the last decade, scholars in the IS discipline have started to re-conceptualize relations between human and material agencies, from thinking about how technology influences humans to examining how actions and relations are materially constituted in practice, and thus sociomaterial in nature (Leonardi, 2011, 2013; Orlikowski, 2007, 2009; Scott & Orlikowski, 2008, 2014). Conceptualizing coordination as a sociomaterial practice is particularly useful to understand how knowledge sharing work is coordinated in real settings (Beane & Orlikowski, 2014; Hilaricus, 2011). At an ontological level, it is possible to conceptualize coordination practices as “constitutive entanglements” of people and CMs in sociomaterial practices enacted in everyday life (Orlikowski, 2007; Scott & Orlikowski, 2008). Coordination activities as sociomaterial practices enact an ad hoc design process in which different networks of people and CMs are temporarily aligned as they interact in ongoing KS practices. From sociomateriality, the deterministic matching approach moves toward a design space in which CMs become an equivalent participant of those dynamics (Latour, 2005) as technology is becoming more ubiquitous and pervasive (Jarrahi et al., 2017).

Research in IS design recognizes that sociomateriality helps IS designers and theorists in understanding the role of CMs in today’s organizational practice (Leonardi, 2013). Some studies have used the sociomaterial perspective to understand how coordination for sharing knowledge occurs in practice (Hilaricus, 2011; Jarrahi, 2013; Pritchard & Symon, 2014; Vieru & Arduin, 2016). Other scholars in the IS discipline have developed some ideas about sociomaterial design of IT artifacts (Bjørn & Østerlund, 2014; Leonardi & Rodríguez-Lluesma, 2012). And recently, KM scholars have been working within a relational ontology to examine the knowledge sharing process using the sociomaterial view (Hilaricus, 2011; Jarrahi, 2013; Pritchard & Symon, 2014; Vieru & Arduin, 2016).
Thus, the sociomaterial approach has offered fresh insights for the study of coordination in practice and provides an important way of thinking about ICT-based coordination mechanisms as parts of contextualized and dynamic networks (as opposed to entities that exist independent of networks) in which technology enacts a network node and not just acts as a mediator of relationships between nodes. Most of the literature about sociomaterial analyzes and discusses ontological positions about relations between people and technology and debates about what could be the appropriate metaphor to name the inseparability between them (Cecez-Kecmanovic et al., 2014; Mikalsen, 2014). As IS designers, we should be able to discuss and learn from how people and CMs are interrelated in practice as part of sociomaterial ecosystems (Bratteteig & Verne, 2012), because technology design is our space for action, accordingly there are recent calls to move from theoretical positions towards design actions.

1.4 Statement of the Problem, Objectives and Research Questions

The work presented in this thesis explores how KMS can be designed following the sociomateriality principles in order to meet knowledge sharing needs of heritage experts (see the application domain in chapter 3). Success in KMS design and usage depends on recognizing variability in the design process but mainly accounting for the sociomaterial dynamics in which both the KMS design process and the environment unfold. This thesis tackles the problem associated with the design of flexible coordination mechanisms that fits the variety of task interdependencies produced via heterogeneity in heritage projects. By understanding coordination activities as sociomaterial practices and designing coordination mechanisms from sociomateriality, it is possible to overcome preliminary advances in sociomaterial design in which applications are explored from sociomateriality but then IT artifacts are designed as socio-technical systems. Therefore, IS design and exploration by using the relational sociomaterial ontology can still provide guidance for improving coordination in knowledge sharing activities.

Existing sociomaterial literature is difficult to apply at the empirical level because it does not provide much guidance about translation of sociomaterial ideas into study designs (Seeber, 2013). Sociomateriality literature emphasizes that use/technology is entangled, but not how (Parmiggiani & Mikalsen, 2013). So far, IS designers lack guidance about how to study sociomateriality in practice, where to start, methodologically and analytically to understand entanglement (Constantinides & Barrett, 2012). Furthermore, the sociomaterial approach does not provide much guidance in specifying how researchers might depict sociomaterial relations empirically in ways that recognize the differences between socio-technical and sociomaterial design (Contractor et al., 2011). At this point, what is problematic in research about sociomateriality is that current IT design proposals are mainly focused on identifying requirements using the sociomaterial lens, but less support about design procedures at an operational level has been offered. Questions about how to design such artefacts that enact inseparability between people and CMs, and how to design sociomaterial CMs in which boundaries are blurred, constitutes nowadays the new challenges for IS designers (Bjørn & Østerlund, 2014).

What is clear at this point is that designing coordination artifacts without reflecting on the underlying design issues related with understanding coordination as a sociomaterial practice, will continue affecting performance in knowledge sharing network settings. This is particularly salient
in the increasingly complex world of ubiquitous and pervasive artifacts which people switch between rapidly, but also a world of material properties that enable knowledge workers to change the CM or the mode of use with just one click, as well as people’s perceptions of affordances and constraints from those CM that compose their personal and group ecosystems. Unless researchers adopt a sociomaterial view in both the design product and design process, there may be little hope for designing better coordination technologies and organizations that meet people’s knowledge needs.

In this thesis, we aim to create a reference architecture for knowledge management systems (KMS) that support coordination in knowledge sharing activities between heterogeneous project teams. In doing so, a clear understanding of coordination for sharing knowledge in the domain of interorganizational and multidisciplinary projects is necessary. A deep understanding of factors affecting the design of ICT-based coordination for sharing knowledge is required to support coordination as ad hoc and flexible activities configured and reconfigured in practice. Consequently, a new sociomaterial design proposal can be formulated as a design artifact that helps IS designers to overcome coordination issues. The intention includes designing and testing a set of sociomaterial design guidelines that support IS designers when designing a KMS using sociomaterial lens. The design guidelines are articulated as a reference architecture which enacts a sociomaterial design process that designers should follow when designing a sociomaterial KMS. The design guidelines also embrace a set of implementation guidelines that aims at helping how IS designers can adopt and implement their own KMS by deriving this from our reference architecture. This also implies an improved understanding of the sociomaterial coordination via an instantiation of the reference architecture in a KMS prototype that also represents the validation of the design artifact. Ultimately, this research can contribute to supporting coordination activities for sharing knowledge between heritage projects which has a big impact in preserving heritage objects that represent an “outstanding universal value from the point of view of history, art or science and enacts our legacy and identity as humans” (UNESCO, 1972). Therefore, we formulate our central research objective as:

RO. “To develop a reference architecture for sociomaterial design of KMS that improve coordination activities for sharing knowledge in the cultural heritage domain”

Consequently, we decompose this main research objective and propose four research questions. Those research questions correspond to the four elements in design science research approach: knowledge base, environment, design artifacts and evaluation. According to these research questions, relevant research instruments are selected. The instruments are discussed later in section 1.5.3. We therefore come up with the following research questions:

RQ1. What are the current issues of the coordination process for sharing knowledge?
RQ2. What organizational and technical factors influence the design of ICT-based coordination mechanisms for knowledge sharing activities between heritage projects?
RQ3. How can we synthesize a reference architecture for designing KMS that supports knowledge sharing activities between heritage projects?
RQ4. To what extent coordination issues are overcome by using a KMS designed via the reference architecture?
In the next section, the research approach for tackling the previous research questions is presented along with the outline of the rest of this thesis.

1.5 Research approach and outline
According to Orlikowski & Baroudi (1991) research approaches in the IS discipline are not grounded in a single overarching theoretical perspective, but exhibit a set of philosophical perspectives about the underlying nature of the phenomenon being investigated, the appropriate research methods to be used, and the nature of valid evidence. In this section, we present the research methodology used to address the research questions in three different dimensions: research philosophy, research strategy and research instruments. A research methodology should describe a certain research strategy, in which a set of research instruments are employed to collect and analyze data on the phenomenon studied, guided by a certain research philosophy.

1.5.1 Research philosophy
The research philosophy underlines the way in which data on the phenomenon studied is collected and analyzed. The research philosophy provides the ideological basis of a methodology. The philosophical grounding of the design science research framework involves ontological and epistemological assumptions that shift as the project runs through design science cycles (Vaishnavi & Kuechler, 2004). Ontology describes the nature of reality, e.g. what is real and what is not real (Galliers, 1992; Vaishnavi & Kuechler, 2004). Specifically, there are two ontological foundations upon which the study of IS from sociomateriality approaches can be built: agential realism and critical realism.

Agential realism contends that reality is constructed inter-subjectively with tools and processes used to describe phenomena (Scott & Orlikowski, 2013). From an ontological point of view, agential realism treats reality as is constructed inter-subjectively in our attempts to represent it; from an epistemological point of view, it treats knowledge about the natural world as something that is not only tied to but inextricably bound with the technologies we use to observe it (Barad, 2003). Orlikowski’s view of sociomateriality rests on two main agential arguments. First, the use of technology is social and as a consequence technological artifacts are buffered and shaped by social interaction. Second, there is no separation between technological artifacts and technology use, accordingly there is no ‘social’ that is separate from ‘material’, there is only the sociomaterial. From this perspective, an analytical separation in a particular situational context is only possible via an agential cut (Barad, 2003). The agential cut is the only way to draw boundaries between what is social and material (Barad, 2003).

Critical realism contends that artifacts’ properties do exist independently of their observation (McLaughlin, 2015), and recognizes the potential existence of a reality beyond our knowledge or conscious experience. The critical realist approach attempts to explain sociomateriality as the process of imbricating human agencies with material agencies, as Leonardi has posited in his work. Within IS research is based on three analytical principles: (1) ontologically, the material is preconceived for being used by people and it is independent of our knowledge; (2) epistemologically, knowledge is limited and always mediated by our perceptual and theoretical
lenses; and (3), different objects of knowledge exist (material, social and conceptual) and each one enacts different ontological and epistemological characteristics (Mingers, Mutch, & Willcocks, 2013). Critical realism changes the focus of the relation between things and humans from intra-action to interaction which describe how things come together and produce emergent features (Niemimaa, 2016). Emergence and interaction depend on time, space and context so that the relations are episodic and so an analytical and ontological separation of people and material artefacts is possible.

Although the two perspectives seem similar, they differ in how they treat human intent and properties of an artifact. Critical realism assumes two separate entities that appear to become inseparable over time, whereas agential realism sees human agency and artifacts as being mutually constructed (Leonardi, 2013). While critical realism highlights how sociomaterial practices have a trajectory based on explicit temporality, or a forward moving direction (Leonardi, 2013), agential realism focuses on how sociomaterial practices have boundaries (Orlikowski, 2007, 2009). Agential realism considers sociomaterial practices as grounded on internal relations – intra-action, whereas critical realisms build on external relations – inter-action (Leonardi, 2013). Intra-action explains how things exists only in relation to other things and how the properties and boundaries of a thing are dependent on the relation; meanwhile, interaction describes how things come together and produce emergent features through their interaction (Niemimaa, 2016). In this sense, critical realism can talk about technology’s materiality while agential realists in principle cannot. There are discussions about what type of realism is adequate to support sociomaterial understandings (Cecez-Kecmanovic et al., 2014; Leonardi, 2013; Niemimaa, 2016), however we do not aim to extend them but to argue which approach can better support consistency and coherence in a design process built with sociomaterial tenets.

The choice of a research perspective should be based on the research objective rather than the research topic (March & Smith, 1995). In section 1.5, we stated that the objective of the research was to develop a reference architecture for designing KMS that improve coordination activities for sharing knowledge in the cultural heritage domain. Ontologically, the problems and challenges to design coordination mechanism for sharing knowledge, are subject to revision as the research proceeds and more knowledge is obtained. In this research, coordination issues and artifact design challenges are seen as objects of design and study that can be observed empirically, but are given meaning only through the context of the domain of application and in relation to a particular knowledge base. Several scholars have recognized that critical realism is an adequate ontology for DSRIS research (Carlsson, 2006, 2010; Carlsson, Henningsson, Hrastinski, & Keller, 2011) and for sociomaterial research (Cuellar, 2016; Leonardi, 2013; Niemimaa, 2016). But also, this philosophical stream is consistent with the goal of improving coordination for sharing knowledge by changing (designing and re-designing) one (or more) of the constituents of the sociomaterial relationship characterizing the situation (Bratteteig & Verne, 2012). By selecting critical realism, we engage with the Leonardi’s perspective of sociomaterial design. In section 2.5, we explain the conceptual groundings that leads the sociomaterial design process developed in this thesis.

Regarding epistemology, it explores the nature of knowledge to determine what kind of knowledge can be obtained and what are the limits to that knowledge (Galliers, 1992; Vaishnavi & Kuechler, 2004). Two major research perspectives are used to study organizational phenomena: positivism
and interpretivism (Galliers, 1992). Positivists claim that reality can be observed and described objectively without interfering with the phenomenon being studied. Descriptions are made in terms of law-like generalizations, of an identical form to those in the natural sciences, and that knowledge can therefore be acquired through the collection of value-free facts (Nandhakumar & Jones, 1997). Positivist studies are recognized by evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and drawing of inferences about a phenomenon from the sample to a stated population (Orlikowski & Baroudi, 1991). Interpretivists claims that reality can be only understood through the understanding of human and social interaction by which the subjective meaning of the reality is constructed (Walsham, 1995). Interpretivism has no basis in deterministic perspectives nor imposes a priori understanding on it, but it attempts to explore the phenomena of interest in its natural setting. Interpretivist studies are recognized by not following any positivist indicators, by reaching domain actors as primary sources of understanding the phenomena, and by examining the phenomena with respect to the cultural and contextual circumstances (Walsham, 1995).

In this research, interpretivism is the epistemological basis that aims at a contextualized understanding of sociomaterial coordination design, connecting the ontological considerations based on critical realism with the observation and validation methods. We will address our objective by constructing a reference architecture for IT-based coordination artifacts. Then, knowledge is obtained through exploring a case study, making artifacts and validating them, and all activities are iterative in nature. The case study is interpretive in the sense that it approaches the empirical observations through the lens provided by the conceptual framework and interpret their meaning within the context of the case. Making artifacts implies to observe and evaluate the design artifact performance during and after each design cycle, interpreting findings according to the application domain needs and the knowledge base. Validation aims at evaluating the reference architecture as an artifact for designing KMS that afford flexible, ad hoc and contextual coordination in practice. All these activities were carried out through several interactions with experts in their natural environment from which researchers: observe their behaviors when developing a heritage project at different situations and stages, abstract the design requirements, gathered feedback, design the KMS jointly with some of them, and evaluate and validate the KMS and the architecture to identify whether the system help them to improve coordination activities for sharing knowledge between heritage projects. The keyword is “improve” which is value-oriented (S. March & Smith, 1995) and so we aimed to share value with heritage experts by involving them in several stages of this doctoral research.

As a summary, the philosophical perspective for the research presented in this thesis takes design science as the overall strategy, supported with a case study and prototyping and resting on the philosophical assumptions of design science with an interpretive epistemology and critical realist ontology. The section 1.5.2 describes the DSR approach in detail.

### 1.5.2 Research strategy
A research strategy outlines the steps to be taken in a scientific inquiry to reach the research objective. We applied the design science paradigm discussed by Hevner, et al. (2004) to carry out the research. The design science paradigm has its roots in engineering and the sciences of the artificial (Simon, 1996). The integration of design science research in the IS field is grounded in
the Hevner’s work, establishing design science research in information systems (DSRIS). DSRIS is a research paradigm for problem solving based on human and relevant issues that are addressed via the analysis, design, implementation, management, and use of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. DSRIS combines a focus on the IT artifact with a high priority on relevance in the application domain (A. Hevner & Chatterjee, 2010). A DSRIS contribution requires to identify a relevant domain problem, demonstrating that no solution exists, developing an ICT artifact that addresses this problem, rigorously evaluating the artifact, articulating the contribution to the ICT knowledge-base and to practice, and explaining the implications for ICT management and practice (S. T. March & Storey, 2008). The designed artifacts are both useful and fundamental in understanding that problem (Gregor & Hevner, 2013; A. R. Hevner, March, Park, & Ram, 2004). The concept of artifact means something that is artificial, or constructed by humans, as opposed to something that occurs naturally (Simon, 1996).

The design science framework presented in Hevner et al. (2004), decouples the previous goals into three distinct but interrelated research cycles, as shown in Figure 1-1.

![Figure 1-1 Design Science Research cycles, adapted from (A. R. Hevner, 2007)](image)

In the design science framework, the relevance cycle is enacted by identification of requirements and field-testing of an artifact within an environment, while rigor cycle is achieved by grounding the research in the existing knowledge base including foundations, methodologies and design theories that subsequently are improved thought the design process. The design aspect is achieved through a design cycle in which the artifact must be built and evaluated thoroughly before “releasing it” to the relevance cycle and before the knowledge contribution is output into the rigor cycle (A. R. Hevner, 2007).

In this research, we advocate using the design science paradigm to create and evaluate a reference architecture for KMS (artifact) to solve coordination issues for sharing knowledge in interorganizational and multidisciplinary networks that we identified and discussed in Chapter 3. The artifacts that are created include a design process and an instantiation that prototypes a type of system solution. However, we followed the behavioral science paradigm at the initial phase to develop a descriptive model and the requirements of the problem situation.
The choice of DSR as research strategy is based on the nature of the research problem, on the status of theory development in the research field, as well as on the coherence with the research philosophy in Section 1.5.1. The research problem was considered to represent an ill-structured problem (A. R. Hevner et al., 2004; S. March & Smith, 1995). According to Sol (1982), ill-structured problems are vague and do not fulfill the following requirements:

- the set of alternative courses of action or solutions is finite and limited;
- the solutions are consistently derived from a model of the problem situation that shows a good correspondence with reality;
- the effectiveness or the efficiency of the courses of action can be numerically evaluated.

The problem we studied in this research exhibited characteristics of an ill-structured problem because the alternative courses of action for providing solutions are unlimited. A great number of alternative solutions could provide support for the design of ICT-based coordination mechanisms for sharing knowledge between heritage projects. In addition, considering the complexity and dynamics of both coordination and design activities in real settings, there is probably no model available with sufficient correspondence from which solutions can be derived in an exact way. Consequently, we follow the DSR guidelines proposed by Hevner et al., 2004 to develop a reference architecture for KMS (artifact) that improve coordination in knowledge sharing activities.

Our DSR strategy is based on critical realism. Information systems scholars keep an ongoing discussion about what is the proper philosophical grounding to design technology. Although, often in the IS design science research underpinning philosophies and ontological views are not explicitly exposed, it frequently seems to be based on positivism, traditional realism, or pragmatism (Carlsson et al., 2011). However, there is a growing interest in grounding information systems research in ideas derived from the philosophical tradition of critical realism (Mingers et al., 2013). Although, the most influential writer on critical realism is Roy Bhaskar, Archer’s work extended the idea to the social arena by discussing the relationship between structure and agency in a morphogenetic way in which social structures can be adapted over time. Her work has strongly influenced Leonardi’s ideas of sociomateriality, specifically through the notion of “analytical dualism” that treats social and material entities as interacting temporarily with each other while all keep distinct from one another (Archer, 1995, 2000).

The potential of critical realism for IS design science research has already been discussed in the IS literature (Carlsson, 2006, 2010; Carlsson et al., 2011; Koponen, 2009; Uppström, 2017). Koponen (2009) argue that critical realism meets the underlying philosophy for design science, as critical realism has implication for what can be said about both the design product and the design process. Johnston and Smith (2010) pointed out the usefulness of critical realism though clarifying the discussion of validity research oriented to empirical, theoretical and evaluation settings. Critical realism allows IS designers to focus on real design problems, in order to gain a better understanding of meaning and significance of information systems artefacts in terms of design and use. According to Carlsson’s work, DSR from a critical realist perspective assumes an objective ontology and a subjective epistemology. The former means that reality exists independently of our investigation on them, whereas a subjective epistemology means that facts
and observations are obtained through intervention and guided by theory. The critical realist view of DSR recognizes complexity in social settings, so that the generated design knowledge will probably be provisional, incomplete and extendable (Carlsson, 2010). Drawing upon the Carlsson’s connection between DSR and critical realism view, in this research we aim to deeply understand why and how a KMS works through designing it from a set of sociomaterial design guidelines in order to solve coordination issues and improve knowledge sharing in the heritage domain. We also attempt to specify for whom and in what circumstances the design guidelines work under contextual constraints. In doing so, our overall DSR process consisted of three DSR iterations, as follows.

**Iteration 1: Understanding the heritage domain and eliciting requirements**
Since DSRIS is issue-driven (A. R. Hevner et al., 2004), the Relevance Cycle guided the start of this research. Preliminary exploration of the RedPHI was conducted in order to get deeper knowledge about the heritage domain but mainly about what domain experts considered initially as problematic from coordination for sharing knowledge. The Rigor Cycle then began with establishing a conceptual framework for studying coordination in practice and for identifying the limits of the knowledge-base that constitute an opportunity for theory extension, i.e. dynamic coordination (P. A. Jarzabkowski et al., 2011) and its sociomaterial view (Constantinides & Barrett, 2012). This led back to the Relevance Cycle for a case study in which observation of coordination for sharing knowledge provided empirical content to the theoretical concepts and contributed to identifying the role of materiality in coordination practices, the coordination issues and the specific requirements (Baskerville & Pries-Heje, 2010). Afterwards, we performed a Rigor Cycle by drawing on the existing body of knowledge regarding KMS design, and theoretical and empirical insights about coordination for knowledge sharing. As a result, sociomateriality emerged as an alternative approach to fill the research gap when designing KMS. In the Design Cycle, we derived a set of meta-requirements (Walls et al., 1992) that lead the KMS design. For each identified meta-requirement, we provide first our reasoning followed by corroboration through empirical evidence and literature insights.

**Iteration 2: Formulating of design guidelines**
For the second iteration, a systematic literature review about sociomaterial concepts was used as input in the Rigor Cycle. We identified different philosophical positions about sociomateriality as well as the current understandings, advances and challenges in the design of IS artifacts. Some frameworks, guidelines, affordances and artifacts were identified and explored as part of the actual state of the art in sociomaterial design. For the Relevance Cycle, we used the conceptual framework of sociomateriality as a lens for reviewing the existing evidence collected from the RedPHI case study during requirements elicitation activities, identifying empirical content for designing KMS from sociomateriality. At this point, a new and detailed iteration of the case study was conducted to get deeper knowledge about sociomateriality in practice. To elucidate an initial set of sociomaterial design guidelines, we held design workshops as part of the Design Cycle. Following the empirical insights from the Relevance Cycle, the conceptual framework supporting sociomaterial design in the Rigor Cycle, and the design workshop outcomes, the final set of sociomaterial design guidelines was abstracted and formulated. In the end, the design framework was evaluated through an expert review session based on the understanding of the coordination
problem for sharing knowledge and the sociomaterial philosophy, allowing for continued engagement with the third iteration of our DSR process.

**Iteration 3 – Testing the design guidelines**
The third iteration began with a Design Cycle. Meta-requirements and design guidelines were used as input in this phase. A KMS designed through our design guidelines was presented as a testable prototype to meet specific requirements for sharing knowledge between heritage projects. Several design iterations were conducted in order to reach a prototypical system to be tested in the environment. Our final set of design guidelines was refined through several rounds of building and evaluating a prototypical implementation. In this sense, iteration 2 was connected with iteration 3 in order to adjust the framework, according to experts’ feedback and development insights. Afterwards, the final KMS prototype was evaluated through the application of the Technology Acceptance Model (TAM) to ensure requirements accomplishment. The Relevance Cycle was used to refine the sociomaterial design process during the Rigor Cycle. Finally, results from both the design process and the design product were integrated and presented in the form of this thesis.

**1.5.3 Research instruments**
Research instruments are understood here as the specific methods that are used to execute a particular research strategy. A number of research instruments are used in the field of information systems ranging from case study, field experiment, laboratory experiment, survey, simulation, and action research (Galliers, 1992). The selection of a research instrument depends on the amount of existing theory available, on the nature of the research, and on the type of research question (S. March & Smith, 1995; Vaishnavi & Kuechler, 2004). In addition, the research strategy used to approach the problem also influences the type of research instruments used (A. R. Hevner et al., 2004). Different research instruments were used to carry out this work, including:

- At the initial stage of the research, we used an exploratory case study to understand coordination in practices, identify coordination issues as well as requirements for the KMS that we developed in the research. The case study helped us to describe the relationships, which exists in reality, usually within an organization or between organizations (Galliers, 1992; Yin, 2009), Chapter 3 presents the overall details about the case study.
- To elucidate an initial set of sociomaterial design guidelines, we held two design workshops as part of the design cycle (Chapter 4). The design workshop followed the principles of collaboration engineering (Azadegan, Papamichail, & Sampaio, 2013) consisting of two phases: concept ideation and patterns and priorities.
- Expert review was used as validation instrument at two stages of this research. In DSRIS, descriptive methods like expert reviews can be used in the evaluation of design artifacts in a primary stage where other forms of evaluation may not be feasible (Hevner, et al., 2004). Evidence of the first iteration of the case study was triangulated using an expert review, documentation analysis and direct observations (Chapter 3). Second, the reference architecture was evaluated by conducting an expert review session with nine heritage experts (Chapter 4).
During the design process, we use prototyping as an instrument to test the technology feasibility of the reference architecture. A prototype can present a relatively realistic view of a system as it will eventually appear (Mason & Carey, 1983). Prototyping is useful for gaining understanding of the requirements, reducing the complexity of the problem and providing an early validation of the system design (Bernstein, 1996).

Validation of the KMS prototype built by using the reference architecture was done with TAM (Venkatesh & Bala, 2008). TAM uses the Likert scale, which ranges from “strongly disagree” to “strongly agree” for different constructs related to the artifact to be validated. The detailed validation process is described in Chapter 5.

As a complement for TAM, we conducted a debriefing session with each validation group. Debriefing offers behavioral feedback and exposes participants’ observations about the KMS and the validation session (Fanning & Gaba, 2007). We used face-to-face debriefings to gather more elements that ensure quality of information by checking data accuracy and involving an interpretation beyond the researcher and attendees, adding validity to an account. Debriefing setting and findings are presented in Chapter 5.

1.5.4 Research outline
First, we define the problem and present a description of the research methodology used to address the different issues in Chapter 1, including the research problem and questions addressed in this research. In Chapter 2, we discuss the current theories and approaches in the design of ICT-based coordination in general, and knowledge sharing activities in particular, drawn from the literature, as well as the way of thinking in this research grounded in a sociomaterial lens. We then present an exploratory case study that provides focus on the main issues to be considered in developing KMS and further explains the research problem in detail in chapter 3. We present the meta-requirements abstraction and the reference architecture for the KMS in Chapter 4. In chapter 5, we discuss how the KMS prototype was implemented, and the findings from the validation process. We make an evaluation of the research in Chapter 6, in which we also present our findings, contributions and proposed recommendations for further research. Figure 1-2 summarizes our research activities and deliverables.

1.6 Definitions
The discussion in the previous section about research drivers leads us to several related concepts. These concepts are not always clearly defined, and stakeholders might use the terms differently. We therefore we provide the definitions in this section.

- **Context**: is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves (Dey, Abowd, & Salber, 2001). Context includes different dimensions such as location (where), role (who), time (when), situation (how), interest (what) and utilization (why). A contextual change occurs when any of these dimensions is modified (Casillo et al., 2016).

- **Contextual dimensions** in heritage projects includes many locations (meeting office, fieldwork, customer offices, government places, etc.); exchange information between different actors (project leader, auditors, experts, contractors, service and material providers, public
officials, majors, students, etc.), synchronic or synchronic communication, virtual or on-site knowledge sharing, dual or group meetings, etc.; different project stages (diagnosis, restoration, conservation, intervention, etc.); different interests (building license, inscription to national or world heritage lists, security demolition, first-aid interventions, etc.); among other factors.

- **Application domain**: consists of the people, organizational systems, and technical systems that interact to work toward a goal (A. R. Hevner, 2007). Each object in the application domain has a state, a set of behaviors, and an identity (A. Hevner & Chatterjee, 2010). Knowledge about the application domain can be enacted by requirements and constraints.

- **Affordance**: are the possibilities for action that an object or environment calls forth to a perceiving subject (Fayard & Weeks, 2014). Affordance explains how people who have certain goals might actively reconfigure the material and human agencies in their work practices (Leonardi, 2011).

- **Routine**: are sequential patterns of social action (Pentland & Rueter, 1994)

- **Change in routine**: is the consequence of people’s perceptions of affordances from materials they use in practice (Leonardi, 2011).

- **Change in technology**: is the consequence of people’s perceptions of constraints from materials they use in practice (Leonardi, 2011).
• **Personal artifact ecosystem**: is a set of ad hoc and dynamic sociomaterial relations between artifacts and people who uses it to perform daily activities. The composition of artifact ecologies is closely related to the context of use, and the functional compatibilities of technologies are defined based on the particularities of each context (Jarrahi et al., 2017). The ecosystems feature artifacts and operations that increasingly derive utility from the functional relations they maintain (Kallinikos, Aaltonen, & Marton, 2013).

• **Organization**: describes the central relations that constitute a system as a whole and determine its type. Systems of the same type have the same organization (Mingers, 1991).

• **Structure**: refers to the actual manifestation of a particular example - its actual components and their interactions (Mingers, 1991).

• **Orchestration**: refer to the situated moments whereby the use of specific technologies within a potential constellation, is planned, negotiated and instantiated within a given group (Rossitto, Bogdan, & Severinson-Eklundh, 2014).

• **Situated action**: is the view that every course of action depends in essential ways on its material and social circumstances (Suchman, 2007).

• **Reference architecture**: is considered as “a set of principal design decisions that are simultaneously applicable to multiple related systems, typically within an application domain, with explicitly defined points of variation” (Medvidovic & Taylor, 2010).
2 RESEARCH BACKGROUND: Sociomateriality as a lens for design

This chapter presents the set of kernel theories that support both the elicitation of design requirements for the design product and the theories and concepts used during the design process performed to solve the domain problem. Additionally, this chapter represents the rigor cycle of the design science research framework to build the knowledge base for the research. As we want to improve coordination activities for sharing knowledge, both concepts are researched independently and then, jointly in the domain context. In order to be able to demonstrate that the instantiation of the reference architecture can result in improvements for coordination for sharing knowledge, we need a knowledge base to evaluate their advances.

We started exploring literature about knowledge management process as the process with great interest for heritage experts as this research began with a relevance cycle. In doing so, we focused on the knowledge sharing process due to preliminary findings of the case study were grounded on coordination issues for sharing knowledge between heritage projects as experts claimed. Literature insights and empirical evidence led us to understand the knowledge concept from an ontological perspective that differs from the traditional distinction between data, information and knowledge. Therefore, this chapter presents the common perspectives of knowledge as well as the standpoint that fits our contribution to knowledge base and the research in general.

When seeking the understanding about how heritage experts share knowledge, the literature study and the relevance cycle led us to coordination theory. Coordination allowed us to characterize an organization network environment, such as RedPHI, regarding how experts manage smaller problems, units, and tasks as a whole so that they fit together to achieve a project purpose. Coordination theory implies the analysis of task dependences and coordination mechanisms in sharing knowledge between heritage projects. This chapter also presents the IP view of coordination as dominant in the field of knowledge sharing together with some of the limitations it has and what it implies for IS design.

Guided by the literature review about coordination and knowledge sharing processes, and findings from the case study exploration, we uncovered a research gap between the conception and use of ICTs that support coordination for sharing knowledge. This led us to conceptualize coordination as a sociomaterial practice and so sociomateriality was introduced. Thereafter concepts and approaches of sociomateriality were investigated to get a deeper understanding about how the sociomaterial perspective can overcome the matching philosophy in the traditional coordination theory. In addition, proposals in sociomaterial design of information systems were identified, as an input to propose design guidelines for KMS artifacts that improve coordination for sharing knowledge in collaborative networks. The study of sociomaterial produced insights of how scholars understand and apply sociomateriality in real settings. While introducing the above concepts, theories and technologies, we discuss their contribution to our research, answer the first research question and propose fundamentals to answer the research question 2.
2.1 The knowledge sharing process
Most of the definitions of the knowledge concept in the knowledge management - KM in literature are based on aspects related to individual characteristics such as beliefs, sense, decision, understanding, values, experience, intuition, reasoning, thinking, behavior, meaning, ability, memory, among others variables. These aspects emphasize the human essence of knowledge and highlight the individual’s role in its management (Beesley & Cooper, 2008). In this individual view, knowledge is considered as a substance which can be processed through different activities such as reception, circulation, transfer, accumulation, conversion and storage (Gherardi & Nicolini, 2000; Gold, Malhotra, & Segars, 2001). The process perspective follows the hierarchical distinction of data, information and knowledge (Davenport & Prusak, 1998) which allows researchers to work in different disciplinary areas like business, management and engineering using different knowledge perspectives with distinct implications for KM (Alavi & Leidner, 2001).

Based on this perspective, knowledge, whether tacit or explicit, is “out there”, stored in some form of memory (Faraj & Azad, 2012; Gherardi & Nicolini, 2000). However, some authors posit that knowledge does not exist “out there” stored in specific technologies, structures, routines or rules nor “in here”, attributed to one particular person or community (Beesley & Cooper, 2008; Marabelli & Newell, 2012; Orlikowski, 2002). Rather, these scholars argue that knowledge can be conceived as mainly social and embedded in practice (Brown & Duguid, 2001; Gherardi & Nicolini, 2000; Latour, 2005; Newell et al., 2009; Orlikowski, 2002). This practical view of knowledge is evident in knowledge sharing studies within organizations by such scholars as (Beckley, 2003; Brown & Duguid, 2001; Carlile, 2002; Gherardi & Nicolini, 2000; Nicolini, 2012; Tsoukas, 2005). They have in common the idea that knowledge is not a static object, but a dynamic entity enacted according to how actors engage in practice. In this research, we ground in the concept of knowledge sharing rather than knowledge transfer. Knowledge transfer takes the notion of knowledge as an object, remarking separation between knowledge and their owner whereas knowledge sharing consider knowledge as something that is socially constructed in a social setting which cannot be separated from the context or the individual (Paulin & Suneson, 2015), which means a sociomaterial view of knowledge.

Based on a practical perspective, in this thesis we take the notion of knowledge as “an ongoing social accomplishment, constituted and reconstituted in everyday practice” (Orlikowski, 2002). A practice view of knowledge leads us to understand knowledge as emergent - enacted from everyday activities (Orlikowski, 2002); embodied – evident in notions as tacit knowing, experiential learning and physical setting (Madhavan & Grover, 1998; Orlikowski, 2006); and embedded - deep-rooted in the historical and cultural context of our lives and work (Hsiao, Tsai, & Lee, 2006; Orlikowski, 2006). However, another dimension of knowledge is that it is also always material (P. Jarzabkowski, Paul Spee, & Smets, 2013; Lee & Amjadi, 2014; Nicolini, 2007; Orlikowski, 2006; Swan, Bresnen, Newell, & Robertson, 2007). The material view of knowledge means that it does not only depend on relations between humans but also on interactions with non-human actors or materials (physical objects, technologies, rules, standards, documents, discourses, etc.) used in everyday activities (Latour, 2005; Orlikowski, 2009).

This means that materials are no longer “ready-to-hand” to accomplish some tasks, but they are constitutive of social networks (Latour, 2005), activities and identities (Scott & Orlikowski,
In Orlikowski’s words, “entities, whether humans or technologies, have no inherent properties, but acquire form, attributes, and capabilities through their interpenetration” (Scott & Orlikowski, 2008). Thus, knowledge can be viewed as a shared social construction based on practice and situated in the historical, sociomaterial, and cultural context in which it occurs (Gherardi & Nicolini, 2000; P. Jarzabkowski et al., 2013; Lee & Amjadi, 2014; Orlikowski, 2006). Drawing upon the sociomaterial perspective (Scott & Orlikowski, 2008), this approach considers knowledge as being inextricably tied to the material and social circumstances in which it is acquired (Gherardi & Nicolini, 2000; Hilaricus, 2011; Newell et al., 2009). According to Orlikowski (2002), circumstances are ongoing assemblages of context (time and place), agency (intentions, actions), and structure (normative, authoritative, and interpretive). From this relational perspective, knowledge is embedded in networks formed by combining members, coordination mechanisms, contexts and tasks, and enacts a way of distributed social expertise; that is, knowing in practice situated in the historical, sociomaterial, and cultural context in which it occurs (Orlikowski, 2002).

Interorganizational knowledge sharing has been analyzed through several factors such as the resources and capabilities of both the donor and recipient firms, the nature of knowledge that is being exchanged, the inter-organizational dynamics (Easterby-Smith et al., 2008), the quality of the relationship (Inkpen & Pien, 2006), prior experience (Kogut & Zander, 1995), external environment (Zorina & Avison, 2011) and heterogeneity (Cummings et al., 2013; Lertpittayapoom, Nongkran, 2005). Traditionally, the knowledge sharing process has been considered as a dyadic exchange of knowledge between a source and a recipient unit, either people, teams and organizations (Fang, Yang, & Hsu, 2013; Szulanski, 1996; Szulanski, Ringov, & Jensen, 2016; Van Wijk, Jansen, & Lyles, 2008) or the integration of the specialized knowledge of multiple individuals (Grant, 1996, 2013) or an attempt to replicate coordination activities of specific resources from one context to other (Kogut & Zander, 1992; Williams, 2007). These perspectives are based on an ontology of separateness (Suchman, 2007) between units/actors, technologies and context, that is an ontology of separating the social and the material even though they need to be entangled into a coherent whole.

Based on the ontology of separateness, a diverse set of knowledge sharing models has been formulated following three different approaches: instrumental, mediation and processual. The Instrumental approach considers materials, particularly ICT-based coordination mechanisms, as independent variables which affect directly or indirectly the organizational effectiveness. This approach treats technology as a specific and relatively distinct entity that interacts with various human aspects (motivation, behavior, attitude, trust, fear), considering it as an independent variable (facilitating conditions, ICT, resources, factors) having a range of effects at different levels of analysis (individual, community, organizational, inter-organizational) on diverse knowledge sharing activities (capture, transmit, absorb, transfer) and on organizational outcomes such as innovation, team performance, user satisfaction and benefits (Hendriks, 1999; Jennex & Olfman, 2010; Jeon, Kim, & Koh, 2011; Svetlik, Stavrou-Costea, & Lin, 2007).

Instead, other knowledge sharing studies represent a mediation approach treating ICT-based coordination mechanisms as a moderating entity that variously influences the relationship between human aspects, knowledge sharing activities and specific outcomes (L. Chen & Fong,
Both the instrumental and mediation approaches adopt technology as an exogenous force testing their effects in the KM processes and organizational performance, formulating general explanations and predictions beyond the nature of technology and its study contexts, and using a variance logic and meta-analysis (Candace L. Witherspoon, Jason Bergner, Cam Cockrell, & Dan N. Stone, 2013; Van Wijk et al., 2008) as a way to provide empirical generalization. Finally, in the processual approach, the ICT-based coordination mechanisms, knowledge sharing activities and outcomes are no longer considered as dependent or independent variables but rather they follow a mutual, integrative, and co-evolving relation over time (Bechky, 2003; Carlile, 2002; Pan & Scarbrough, 1998) in which technologies serve as boundary objects to afford knowledge sharing across dissimilar communities.

In summary, the instrumental, moderation and processual approaches for sharing knowledge consider ICT-based coordination mechanisms as tools that can be inserted, modified, connected or removed, addressing it as another variable affecting the organizational performance. Although considerable research has followed the epistemological perspective of “how” people interact with each other through technology, less attention has been paid to both ontological reflections and evidence of “what” specific material features of technology people use and what possibilities materiality affords people to share knowledge.

2.2 Examining the knowledge sharing barriers

Traditional research on KM generally posits an agreement about the distinction between human oriented (social, organizational, people-centered) and technology oriented (technological, technology-centered) KM approaches (Maier, 2007). The technology-centered approach is driven by the tangible aspects of KM as the “hard” part of knowledge (e.g. KMS, decision support systems - DSS, etc.) and it is focused mainly in the storage, retrieval, codification and documentation processes (Ling, 2011; Perez & Pablos, 2003; Tierney, 1999). Human orientation is driven by organizational learning and it is focused on the tacit aspects of KM as the “soft” part of knowledge (e.g. learning, identity, culture, appropriation, etc.) and it is focused mainly in transfer, creation and sharing processes (Ling, 2011; Perez & Pablos, 2003; Tierney, 1999). These different perceptions are based on the traditional dichotomy between explicit and tacit knowledge where the codified and documented knowledge can be managed through a technology-oriented approach, whereas knowledge that resides in people’s thoughts and beliefs requires people-oriented actions (Bibikas et al., 2008).

Recently, information systems scholars have begun to agree that it is a mistake to concentrate only on the one aspect of KM (ICT tools or human activities), and to ignore the other (Sajeva, 2010). Thus, focus on KM technologies, without consideration of the social processes that surround them, is a recipe for failure (Hasan & Crawford, 2003). Some attempts for considering an integrated view of technological artifacts and human behavior have been proposed in the KM literature following the a socio-technical perspective (Cao, Thompson, & Triche, 2013; Gallupe, 2001; Grundstein & Rosenthal-Sabroux, 2007; McNabb, 2006; Sajeva, 2010). In addition, it is recognized that people and technology must be integrated in order to avoid coordination fails (Ambrosio, 2000) because neither humans nor non-humans actors can - or should - go it alone.
Considering people and coordination technologies performing an inseparable relation, the current knowledge sharing approaches encounter some difficulties. First, coordination mechanisms are analyzed from a deterministic perspective where it causes some effects or changes in KM process or directly in the organizational performance (e.g., efficiency, effectiveness, differentiation, financial, market share, innovation, alliances, etc.). In this regard, seeing technology as an exogenous force that can be inserted in an organizational setting ignores or overlooks the social context as well as the history and human agency involved in technology design, construction and use. Often it is assumed that technology will operate without human intervention as intended and designed across time and place (Orlikowski, 2007, 2009; Scott & Orlikowski, 2008). In this perspective, the ICT-based coordination mechanisms are relevant only when knowledge needs emerge and they are seen to be of particular interest at certain times, in explicit places, during special organizational circumstances or when it fails. Consequently, considering mechanisms as an individual and stable phenomenon that does not change as contextual dimensions do, limits the possibility of seeing, from a holistic view, how coordination is an integral part of all knowledge sharing contexts and situations.

The second difficulty lies in the relationship between ICT-based coordination mechanisms and humans as interrelated in some way. In this logic, the nature of the relationship entailed is relevant to study, specifically, whether it holds an unidirectional causal influence (e.g., technology influencing knowledge codification for knowledge sharing improvement) or a mutual interaction (as in the process perspective where technology constrains or enables knowledge sharing and this process, in turn, determines IT changes) (Orlikowski, 2007, 2009; Scott & Orlikowski, 2008). Although these knowledge sharing perspectives have been developed assuming that people, process, technology, and organizations should be integrated, scholars still acknowledge that coordination mechanisms and humans are essentially different and separate realities. This ontology of separateness, on the one hand enables scholars to talk about technologies and allows quantifying its effects in the KM and organizational performance, which is the dominant perspective in KM performance measurement research (Kuah & Wong, 2011; Wong, Tan, Lee, & Wong, 2015). But, on the other hand, the separation makes it difficult to see how technologies are rarely integrated, appropriated, effective, and infallible, and how they can make powerful or wear down the knowledge sharing activities.

2.3 Overview of the coordination theory and its dominant approach
Alignment of interdependent organizational activities has long been a main concern for many organization theorists (Galbraith, 1974; J. G. March & Simon, 1958; Thompson, 1967; Van de Ven, Delbecq, & Koenig Jr, 1976). Early theories of coordination focused on the need to balance differentiation among organizational units, with integration being achieved through coordination mechanisms (Galbraith, 1974; J. G. March & Simon, 1958; Thompson, 1967). Prior approaches to understand coordination were formulated as of manufacturing and production approaches and based on organizational theories of the design of work and design of management systems (Okhuysen & Bechky, 2009). However, contemporary stages of coordination theory (Malone & Crowston, 1994; Malone et al., 1999) are interdisciplinary and generic, and they draw heavily upon the Information processing - IP view of organizations. The IP-view of coordination has roots in a variety of disciplines such as computer science, information systems, and sociology of work (Okhuysen & Bechky, 2009). The main idea of the IP view is that an organization is an IP system
that must cope with environmental and work-related uncertainty (Galbraith, 1974). Uncertainty means the difference between the amount of information required to perform a task and the amount of information already possessed by the organization (Galbraith, 1974). In order to lead with uncertainty, organizations can fit requirements and capacities (Daft & Lengel, 1986) through reducing the amount of information that is processed or increasing its capacity to handle more information (Galbraith, 1974).

From the IP-view, coordination can be defined as the act of managing interdependencies between activities (Malone & Crowston, 1990). Designing a coordination process implies to identify and match dependencies and coordination mechanisms (Peltokorpi, 2014). Interdependencies refer to goal-relevant relationships among tasks (Malone & Crowston, 1990). Interdependencies generate incremental IP needs, but when interdependency is higher, a coordination mechanism can facilitate or affect the IP capability of the organization (Nova & Gonzalez, 2016a). Coordination mechanisms (CMs) are the organizational arrangements that allow individuals to realize a collective performance (Okhuysen & Bechky, 2009), providing affordances and constraints to articulation work (Cabitza & Simone, 2011).

Following the IP principles, interdependencies can be classified as resource flow, fit and sharing (Malone et al., 1999). Flow dependencies occur when an activity produces a resource that is used by other activity. For instance, in cultural architectural heritage activities, task complexity depends on many rules and procedures for managing information such as get approvals from the local or national authorities for a conservation plan in order to protect a heritage object before starting the physical restoration activities. Fit dependencies arise when multiple activities produce a single resource. As an example, let’s consider a conservation plan for a heritage object that must integrate different outcomes from architectural analysis, pathology reports, structural examination, etc. Finally, sharing dependencies occur when multiple activities use the same resource. Using the example above, the final draft of the conservation plan must be reviewed by the project team and then get feedback from local authorities, the object owner, and the funding institution.

Complementary, coordination mechanisms can be classified as: standards, mediation and mutual adjustment (Galbraith, 1974; Thompson, 1967; March and Simon, 1958). Standard-based mechanisms are considered an a priori specification of codified guidelines, action programs and specific goals (J. G. March & Simon, 1958; Thompson, 1967) where the verbal communication and the interaction among actors is not necessary for coordination (Galbraith, 1974). Examples in the heritage domain include governmental policies, intervention plans, management plans for protection, thesauri, among others. Mediation-based mechanisms involve a third actor typically located at a higher level that acts as mediator between two organizational units (Gonzalez, 2008). Some examples in the heritage domain are technical committees, technical reports, hierarchies, labor division, and others. Mutual adjustment mechanisms are based on the expected reciprocal communication between actors (Thompson, 1967). Unlike standards-based mechanisms, communication and interaction in heritage projects is achieved through personal channels between peers such as scheduled and unscheduled meetings, instant messaging, video conference, email, others.
As a result of this perspective, literature has emphasized the distinction between different modes of coordination, for example, by program or feedback (J. G. March & Simon, 1958), impersonal versus mutual adjustment (Van de Ven et al., 1976), rules or programs, hierarchies and target or goals (Galbraith, 1974), and programmed versus non-programmed (Argote, 1982), rules and directives, sequencing, routines and group problem solving and decision making (Grant, 1996), task-task, task-resource and resource-resource (Crowston, 1994) and structural and formal, hybrid/overlaying, informal and internal markets (Reger, 1999), among others.

2.4 Limitations of coordination theory

Nowadays, people’s everyday environments are flooded with digital and material artifacts (Jarrahi & Thomson, 2017) and this ICT diversity affords them many possibilities to become coordinated using different technologies with different members, in different ways, and at different times, according to the context and situation dynamics. In fact, coordination should be flexible enough to cope with uncertainty, novelty, complexity and ambiguity in every application domain. However, currently there is a tension in the coordination literature between its reification as standardized procedures and its dynamic and emergent behavior enacted in practice. Following early approaches to understanding coordination (Crowston, 1997; Malone & Crowston, 1990, 1994; Malone et al., 1999), a taxonomy of interdependencies and coordination mechanisms can be derived and listed as a coordination handbook (Malone et al., 1999). Typically, the matching process is performed beforehand (in planning mode) enacting a static view of coordination in which no improvised acts are needed (Constantinides & Barrett, 2012). This early coordination design philosophy assumes that the “environment is predictable enough to characterize existing interdependencies and that predefined mechanisms can be designed for various contingencies” (Faraj & Xiao, 2006) and so it is possible to identify the whole set of interdependencies in an organizational setting and then to build a coordination library to match them (Malone et al., 1999).

Prediction means the possibility to control the whole organization interactions, reducing or eliminating improvised acts. However, both literature study (Faraj & Xiao, 2006; Gherardi & Nicolini, 2000; P. A. Jarzabkowski et al., 2011; Okhuysen & Bechky, 2009) and our practice exploration in the case study (see Chapter 3) revealed many reasons that contradict the matching process between mechanisms and dependencies. First, formalized, designed, planned, or engineered CMs do not properly meet tasks uncertainties in knowledge work because task characteristics, boundaries and order become blurred an so difficult to identify (Okhuysen & Bechky, 2009). Second, coordination is difficult to convert into patterns as inputs for predictive models because people use, switch, toggle, substitute and combine multiple and different CMs according to contextual and situational dimensions in which they participate everyday (Contractor et al., 2011; Cummings & Kiesler, 2008; Hovorka & Germonprez, 2011). Third, CMs should meet the emergence of numerous, complex and improvised tasks because knowledge work is primarily performed by heterogeneous teams in a timely manner (Faraj & Xiao, 2006). Fourth, CMs should be rapidly and temporary configured to fit coordination needs in ad hoc, collaborative, and non-bureaucratic settings (Gonzalez, 2010).

Despite coordination and knowledge sharing limitations, organizational designers still continue designing coordination work by using the IP-view (Levitt, 2012; Lindberg, Berente, Gaskin, &
Lyytinen, 2016), avoiding the contextual dimensions of coordination practices and considering an ontological separation between interdependencies and coordination mechanisms (Bolici, Howison, & Crowston, 2016). CMs should be designed without the deterministic approach of the IP-view, moving the design process towards a context-aware design space in which coordination happens between and within personal artifact ecosystems (Jarrahi, 2012). An artifact ecosystem enacts the ways in which users, as individuals or collectives, design multiple configurations of materials, appropriating and adapting different constellations for different purposes (Bodker & Klokmose, 2012; Jung, Stolterman, Ryan, Thompson, & Siegel, 2008). The combination of artifacts composing the ecosystem is highly contextualized and situated so that affordances of technologies are based on the particularities of each context.

The issues mentioned above show that designing coordination of knowledge from the IP-view have some conceptual and practical limitations that lead designers to consider CMs as a design problem (Burton & Obel, 2018). These limitations uncover a gap between the conception and use of ICTs that support coordination, and a lack of understanding about how this gap affects the knowledge sharing process. This issue exceeds the scope of the mainstream IP view of coordination because coordination problems in knowledge sharing are not a matter of information quantity or IP capacity. Rather, coordination issues are about how people and coordination technologies are intertwined dynamically in practice according to contextual dimensions. The core inquiry is about how technological diversity and heterogeneity have changed the coordination focus from apply cognitive models and structures to particular situations towards using those situations to accomplish coordination actions. Ultimately, efforts to improve the KM performance should not be focused in just one factor such as technology or people, but it should be planned and implemented from an entanglement perspective. This shift implies that KM researchers should overcome the ontological and epistemological distinction between coordination technologies (or mechanisms more generally) and people (or interdependencies) so that an alternative coordination approach is needed.

2.5 The way of thinking in this research: Sociomateriality

The way of thinking portrays the concepts and theoretical foundations of sociomateriality to enhance coordination for sharing knowledge. The present research is grounded on the proposition that the broad banner of sociomateriality (Leonardi, 2011, 2013; Orlikowski, 2007; Scott & Orlikowski, 2008) presents us an opportunity to re-conceptualize coordination. This re-conceptualization leads us to change our understanding from thinking about how coordination technologies as discrete artifacts can influence the knowledge sharing process to examining how coordination mechanisms and actions are materially constituted in knowledge sharing practices, and they are, thus, sociomaterial in nature. Sociomateriality is practice-oriented and enacts the dynamic and emergent characteristics of coordination, affording scholars and practitioners with possibilities to overcome the analytical language of separateness between coordination mechanisms and interdependencies by a relational language in the sense of the actor-network theory (Callon, 1984; Latour, 2005; Law, 1987). This relational ontology (Law, 2009) suggests that all coordination practices are always configured by some specific sociomateriality, and thus for studying coordination in the knowledge sharing process, we must study the dynamic and emergent sociomaterial (re)configurations as coordination activities are performed in practice.
The concept of sociomateriality in the information systems discipline rests on the seminal work of Orlikowski and Scott (Orlikowski, 2007, 2009; Scott & Orlikowski, 2008) and Leonardi (Leonardi, 2011, 2012, 2013) and draws on the actor-network theory (Callon, 1984; Latour, 2005; Law, 1987). Sociomateriality breaks the traditional view of IS which separate human beings and things - the social and the material - because they are considered as independent and self-contained entities that interact and affect each other (Scott & Orlikowski, 2008). The main idea about sociomateriality is that people and technology are inherently inseparable and represent dynamic and shifting assemblages as they interact in ongoing practices (Orlikowski, 2009). These assemblages involve human and non-human actors as equivalent participants (Latour, 2005) that temporarily align to achieve particular effects, and that are no longer considered just as organizational actors (Inkpen & Tsang, 2005; Van Wijk et al., 2008) or units (Argote, McEvily, & Reagans, 2003; Szulanski, 1996; Williams, 2007). Actually, organizational actors and units are regularly recognizable as being individuals but they are an ambiguous specification of what Latour calls ‘actants’ which denote human and non-human actors taking shape when they interact or are reshuffled together in a specific context.

In the sociomaterial perspective, technology is no longer subordinated to humans, but rather, both are able to enact agency. Leonardi (2011) defines human agency as the ability to form and realize one’s goals and he also defines material agency as the capacity for nonhuman entities to act on their own, apart from human intervention. Relations between human and material agencies have been examined as entanglement (Orlikowski, 2007), assemblage (Suchman, 2007) or imbrication (Leonardi, 2011). Entanglement treats the social and material as similar and inseparable; assemblage describes the relation between the social and material as components and how they constitute each other; however, imbrication describes the social and the material as interwoven and not entangled, therefore they are analytically and ontologically separable.

In particular, the following concepts guide this dissertation: imbrication, trading zone conversation, and affordance (Leonardi, 2011; Leonardi & Rodriguez-Lluesma, 2012). The process of imbrication means that human and material agencies are arranged in overlapping patterns so that they function interdependently (Leonardi, 2011). Based on the imbrication concept, human and material agencies are understood as different but act together to produce certain outcomes; this opens a conversation between social and material agencies that allows for design to take place (Bratteteig & Verne, 2012). Material entities have inherent properties that remain stable across time and space, unless some subsequent redesign is undertaken. Such redesign rests on human perception of affordances or constraints in material agency (Leonardi & Rodriguez-Lluesma, 2012).

Leonardi claims that the imbrication metaphor is more appropriate for design, arguing that ‘entanglement’ implies a commitment to treat the ‘social’ and the ‘material’ inseparably, suggesting that the sociomaterial is one thing, not two (Leonardi, 2011). Other researchers also recognize this limitation and conclude that the ‘sociomaterial entanglement’ perspective leaves no space for improvement (Bratteteig & Verne, 2012). Instead, the metaphor of imbrication offers more opportunities for design intervention, as it assumes that sociomaterial assemblages can be disentangled, separately improved and re-arranged according to the affordances or constraints that people perceive from technologies. Acknowledging the empirical separateness and potential
imbrication of these agencies is a necessary move for designing technologies and organizations that work better (Leonardi & Rodriguez-Lluesma, 2012). In this research we use the imbrication metaphor to understand how affordances can lead the design and redesign of coordination mechanisms for sharing knowledge in the heritage domain. Employing the metaphor of imbrication, however, has several implications. First, recognizing that that someone (heritage expert or IT designer) is responsible for putting the social and the material together, but that they were ever separate in the first place. Second, time and space are an important part of the conversation, because affordance perception depends on contextual situations that determine the type and length of the imbrication. And, third, imbrications can be dismounted (Leonardi & Rodriguez-Lluesma, 2012) and there is no ideal or finite number of imbrications.

We draw upon the work of Leonardi (2011, 2013) who argues that sociomateriality is perception-based: when people find that they are unable to reach their goals in the current contextual situation through a technological artefact, they change either its materiality or the organizational routines associated with this technology. In particular, Leonardi argues that the perception of constraints leads people to change their technologies, while the perception of affordance leads people to change their organizational routines. Both perceptions are constructed in the space of imbrication that we call trading zone.

In the heritage domain, a **trading zone** facilitates the conversation through which heterogeneous actors can engage each other about their shared interest in a common material (heritage object) and a common cause (project goal). This space is invented when different communities come in contact around issues of mutual concern. In trading zones, agencies manage to work together through the development of what Galison calls contact languages (Galison, 1997). These languages enact what we call affordance as a linguistic blending that allows both agencies to converse, their goals to converge, and ultimately to imbricate. In sociomaterial design, the trading zone is a space where configuration and reconfiguration of technologies occurs, whether through updating a sociomaterial ecosystem or through designing a KMS for sharing knowledge between heritage projects. The trading zone perspective shows how important it is to consider the concepts of disentanglement, improvement and re-arranging, based on how affordances are perceived, to talk about a space for design (process) and about the possible design in that space (product).

The main difference in the theoretical foundation offered by entanglement and imbrication is that the former overlooks conversations between agencies taking sociomaterial practices as given, ontologically and empirically, while the latter argues that interaction between agencies is done in a trading zone in which negotiations and improvements occur via affordance perception. **Conversations** enact symbolic communication within and between social and material agencies. Conversations can be internal as those that social actors have within themselves thus including cognition, rationality and emotions (Archer, 2000) as fundamental of affordance perceptions, and external, as those conversations between the people and materials they use to carry out their work, as well as conversations between the technologies themselves (Leonardi & Rodriguez-Lluesma, 2012).
Numerous scholars have used the **affordance** concept to study technology – design, adoption, or use – while recognizing social context and agency (Leonardi, 2011; Leonardi & Barley, 2008; Markus & Silver, 2008; Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). However, the concept of affordance is diversely used and understood in the IS literature: Some scholars take a dispositional perspective; others take a relational interpretation, thus reproducing the dualisms between the social and material (Fayard & Weeks, 2014). The concept of affordance, as used in sociomateriality, describe the (user) perceptions of what a certain material object (e.g., technology) permits to achieve (i.e., ‘affords’) and how those perceptions are relational to the object’s materiality (Niemimaa, 2016).

We grounded on the Leonardi’s perspective by adopting a relational approach to affordances, where affordances exist “between people and an artifact’s materiality — artifacts can be used in myriad ways and have multiple effects on the organization of work” (Leonardi, 2011). Leonardi, the concept of affordances goes together with that of constraints, since together they enact the properties that emerge between the material and the social in light of people’s goals and specific contexts. Therefore, affordances and constraints are intermediary concepts that define the ways in which human agency might actively reconfigure the material one in their work practices. Leonardi (2011) draw upon the idea that conversations and negotiations between people goals and materiality of a technology leads to actively construct perceptual affordances and constraints, which in turn, determine further imbrications. Even though Leonardi defines affordances as actively constructed, departing from Gibson’s original attempt to define affordances as directly perceived, he does not provide an empirical illustration of how designers might construct affordances in an empirical way. In this research, we developed the concept of design feature as the material vehicle that afford designers a set of design capabilities to create affordances in the KMS that account for the coordination work needs of heritage experts. Both, design features and affordances constitutes the implementation guidelines that provides operational and tangible landing of the design guidelines. Therefore, our design guidelines enable usefulness by constructing affordances that match the coordination work needs of heritage experts, but also usability by operationalize each guideline through a detailed set of design features enacting the materiality that afford that possibilities for action.

### 2.6 Grounding IS design in sociomaterial tenets

Coordination as a sociomaterial practice enacts mutual and ongoing constitution and reconstitution of contextually situated human activities with CMs (Beane & Orlikowski, 2014; Constantinides & Barrett, 2012; Holeman & Barrett, 2017; Venter, Oborn, & Barrett, 2014). The sociomaterial practices of coordination enact an ad hoc design process in which people perceive different affordances and constraints (Leonardi, 2011) from CMs and so they are temporarily and dynamically aligned through interaction in ongoing practices. The contextual dimensions of coordination practices determine how social and material agencies become entangled (Holeman & Barrett, 2017) and so designers cannot predict but guide the coordination practices.

Even though sociomateriality has contributed to understanding the role of technology in today’s organizational practice (Leonardi, 2013) and in the IS literature (Cecez-Kecmanovic et al., 2014), less attention has been given to the sociomaterial design of artifacts (Constantinides & Barrett, 2012; Contractor et al., 2011; Leonardi, 2013; Seeber, 2013). To the best of our knowledge, there
does not exist much work on guiding design activities for sociomaterial artifacts because scholars are mainly focused on debating about philosophical roots and empirical understandings of sociomateriality (Cecez-Kecmanovic et al., 2014; Constantinides & Barrett, 2012; Mueller et al., 2016; Niemimaa, 2016).

However, some disperse ideas and frameworks has been formulated in the area of information systems discipline. For instance, Bjørn and Østerlund (2014) proposed a design process following the sociomaterial approach in which designers explores bounding practices to design coordinative artifacts. The design process points out to understand how people are related with digital materials which they include or exclude in specific types of bounding according to the usage context (Bjørn & Østerlund, 2014). Finally, Leonardi and Rodriguez (2012), oriented by the design science research approach, propose that designers should start a design process identifying the trading zone in which nested conversations between people and technologies occurs dynamically as the context changes, and then determining how using technology differently might fit people's needs (Leonardi & Rodriguez-Lluesma, 2012). These proposals are mainly focused on identifying requirements using the sociomaterial lens but less on design procedures at an empirical and operational level.

In addition, examples illustrating the application of sociomaterial design in prototypical instantiations of CMs in KM settings are very limited. Digital calendars (Ktistakis & Akoumianakis, 2017), multi-device user interface (Akoumianakis, 2013), multi-agent system (Li, 2017) and tangible user interface (Gonzalez, Cortés Rico, Pérez Bustos, & Franco Avellaneda, 2016) are some examples of artifacts designed from sociomateriality. By mentioning these examples, we did not aim at completeness, but at illustrating the use of sociomateriality in designing IS artifacts. Examples are mainly focused on coordination practices between and within artifact sociomaterial ecosystems but none of them reveal a formal design framework and so this reveals a research gap in IS design from sociomateriality. This gap match with scholars and practitioners calls for both methodological and analytical guidance to trace the entanglement (Constantinides & Barrett, 2012) and design guidelines for technology-based CMs based on sociomaterial thinking (Contractor et al., 2011; Seeber, 2013). Knowledge about the design process need to go beyond elicitation of sociomaterial requirements and should also guide designers in developing, implementing and testing artifacts such as KMS.

2.7 Operationalizing the sociomaterial perspective for design tasks
In this chapter, we had presented how the sociomaterial perspective informs our research work. From a critical realist perspective, we show how it enables the sociomaterial exploration of the heritage domain and permeates the design of the reference architecture, next we present more specific questions that were useful for answering the research question 2. This question lead to identify and understand what organizational and technical factors influence the design of ICT-based coordination mechanisms for knowledge sharing activities between heritage projects. By separating organizational factors (human and social) from technical factors (material) in chapters 3 and 4, we are showing that our research enacts a critical realist view of sociomateriality, in which we consider the social and material as two separated entities with inherent properties, that become imbricated during design activities of coordination mechanisms.
This ontological and analytical separation of agencies leads to methodological inquiries that makes operative the sociomaterial design from preliminary exploration of the case study to the formulation of the design guidelines. Moreover, methodology is another challenge for sociomateriality scholars as we posited in section 1.4. In order to overcome those methodological challenges, we chose to explore separately the coordination practices carried out in the heritage domain, the coordination mechanisms for managing dependencies, and later how coordination mechanisms and knowledge needs, as conversant entities, imbricate to enable knowledge sharing in different trading zones. In doing so, we formulate some specific questions for each exploration as following:

a) Why and how coordination occurs in knowledge sharing practices?
b) How coordination practices come to take in the shape they do?
c) Through which mechanisms knowledge work coordination occurs?
d) What role heritage experts play in coordination over time?
e) What activities heritage experts perform with materials in their ecosystems?
f) How experts understand the way of they interact with coordination mechanisms?
g) How the existing materiality becomes imbricated with the social contexts into which coordination occurs?
h) How the contextual dimensions lead the imbrication process in coordination practices for sharing knowledge?

By fleshing out these questions, we were in a strong position to be able to talk about the role that materiality of the coordination mechanisms plays in coordination activities for sharing knowledge, without resorting to deterministic thinking and without treating materiality as non-existing. Additionally, we also were well poised to understand the role that materiality plays in the ongoing process of coordinating and the constitution of knowledge sharing over time. Chapter 3 present answers for some of these questions and later, in section 4.1, we present how the answering process was abstracted and included as part of the sociomaterial process to identify design requirements and formulate design guidelines.

2.8 Summary
This chapter presented our knowledge base as the answer of Research Question 1. In chapter one, we briefly discussed and defined coordination for sharing knowledge. In this chapter, we provided a sound theoretical background on the domain of knowledge sharing, ICT-based coordination and sociomateriality as kernel theories to help us define the relevant concepts for our reference architecture. Ontological and epistemological approaches to understand the knowledge sharing process are mainly based on a deterministic perspective between human and materials in which both are considered as independent and separate entities that affect each other when they become linked. In turn, those approaches guide assumptions in knowledge sharing studies about what is knowledge and how it is shared in practice.

Literature about coordination is mainly focused in predicted and predefined models which aims to meet knowledge requirements. However, recently scholars have started to claim for flexible and customized CMs as coordination is highly dynamic and emergent, but mainly is enacted in practice where contextual dimensions determine the coordination activities. The sociomaterial lens help scholars to understand how coordination is re(configured) in practice in a non-patterned
way, as people perceive different affordances and constraints from CMs being used and how those perceptions guide the re(configuration) practices. Additionally, literature about sociomateriality recognize that the design of artifacts grounded on sociomaterial principles are still challenging due to the lack of guidelines and sociomaterial design processes that support designers in crossing confidently the fuzzy border between sociomaterial thinking and sociomaterial design.

The sociomaterial design thoughts exposed in this chapter, and its underlying way of thinking, is used as a basis for designing and developing the reference architecture in chapter four. In Chapter 3, we present the problems and issues that domain experts face in coordination activities for sharing knowledge in collaborative networks efficiently and effectively.
3 COORDINATION IN PRACTICE: The REDPHI case study

Following the “Information Systems Research Framework” suggested by Hevner et al. (2004), Design science research point out identify opportunities and problems in an actual application environment in order to solve them through new and innovative artifacts and the processes for building these artifacts (Simon 1996). The environment defines the problem space (Simon 1996) in which reside the phenomena of interest. In DSR, the application domain consists of the people, organizational systems, technologies and infrastructure that interact to work toward a goal. Issues of interest can be related with any of these components or with a mix of them. The purpose of exploring an application domain as part of the relevance cycle of the DSR is dual. On the one hand, the environment provides the specific requirements for an investigation and, on the other hand, it enacts the evaluation space and defines the reliability criteria of the research results. Ultimately, a IS research aims to acquire knowledge and understanding about an unsolved and important business problems in order to develop and learn from a technology-based solution designed to meet domain issues (A. R. Hevner et al., 2004). In this doctoral research, the DSR included an important match between technological needs of RedPHI for managing knowledge and the process of searching an organization to be taken as case study.

Even though literature about coordination and knowledge sharing is prolific, the kernel theory of sociomaterial design for KMS also required a context dependent analysis. In this chapter, we use an exploratory case study to gain insights about coordination issues for sharing knowledge between heritage projects. We performed a deep study about characteristics of the heritage domain itself, but mainly studied how heritage experts get coordinated daily, how knowledge is shared between them, and what kind of coordination issues affect the knowledge sharing performance. The case study findings were abstracted later in order to identify the type of domain problem in knowledge sharing networks. Another result of field-testing was to elicitate the specific requirements as input to the design cycle, setting the opportunity to solve the problem presented. As what we mentioned in the research strategy, we select RedPHI as the target for the exploratory case study. Research Questions 2 will be answered in this chapter.

3.1 Vignette: an example of heritage project

The International Committee for the Conservation of the Industrial Heritage (TICCIH), defines Industrial Heritage as those objects that possess a historical, technological, social, architectural or scientific value. These objects consist of buildings and machinery destined to different industrial processes such as processing, refining, generating, transmitting, transportation, etc., Those activities refer to the “advancement in productive techniques, of science, of the ways of building and modifying the natural and urban context, and the transformation of everyday habits” (Therrien, 2009). The industrial heritage enacts the social memory and identity of the human society transformed over the years through ongoing innovation processes.

Fábrica de Loza as Industrial Heritage
Within the industrial heritage context, Bogotá has a Pottery Factory (Fábrica de Loza) established in 1832, and considered a prototype of the first industries of the last decades of the 18th Century and the beginnings of the 19th Century, not only for Colombia but for the world, since other
examples have been demolished (for example in Mexico) or have suffered profound alterations (as those set in Staffordshire, England) (Therrien, 2009).

A conservation project began in 1999, with an archaeological focus and an interest in valuing and documenting the objects that were produced by this industry. Further, the building’s original characteristics, its present state of conservation, the urban development of the terrain alongside the factory and its impact in the social change and landscape of this area have been identified through several research projects, conducted by a large group of experts from different universities, disciplines, methodologies, institutions and at different times. The Figure 3-1 shows the Pottery Factory in 2016.

![Figure 3-1 The Pottery Factory in 2016](image)

In the heritage studies of the Pottery Factory, explorations have been done by using historical, architectural, archaeological, anthropological, sociological, economical, as well as engineering lenses. However, as the factory has been permanently inhabited after its closure (see Figure 3-2), it is imperative to take into account people directly involved in it. Most of the heritage projects are focused on design and conservation and management plans oriented towards the physical
rehabilitation of the site where the object is located, however, as in the case of the Pottery Factory, this sites are generally characterized by extreme poverty so that heritage projects often start by exploring the conditions of the physical space but necessarily include an exploration of the economic, social and political context which increase heterogeneity in expert teams, disciplinary areas, expertise, research tools, contexts, among other aspects.

In order to protect the architectural, technological and cultural identity values of the Pottery Factory, it is necessary to design and develop a preservation project that, in general, includes an inventory of problems, the required actions for conservation and development, the set of intervention strategies, the interacting actors, legal accounts, among other specific aspects according to the heritage object typology. In the Pottery Factory project several actors and institutions have participated in different sectors such as Academic Sector (Pontificia Universidad Javeriana, Instituto Javeriano de Vivienda y Urbanismo, Faculty of Economics); Public Sector (Departamento Administrativo de Planeación Distrital, Instituto de Desarrollo Urbano, Renovación Urbana, Departamento Administrativo de Bienestar Social, Servicio Nacional de Aprendizaje); Private Sector (Mipymes, Fundación Corona, Radio Cadena Nacional); Financial Sector (BID, UNESCO, Institución de Corporaciones de Ahorro y Vivienda); District – Inhabitants (Single mothers, Infants and juvenile population, Local politicians, The Civic Center COL – Lourdes – La Candelaria). In summary, even though not all heritage projects are as big as the Pottery Factory, what is highly recognized in the heritage domain is the difficulty to coordinate several views of an object of study in order to guarantee the work quality but also the preservation of the human identity and memory through protecting our heritage objects.

3.2 Case study design

The focus of this single-case study was initially exploratory but allowed for going beyond empirical validation of existing theory (Yin, 2009) and into development of new theory from empirical data (Eisenhardt, 1989). The case study was aimed at identifying empirical coordination problems in KM projects that are subsequently transformed into design requirements, which, together with kernel theories, become inputs for the reference architecture instantiated via a KMS prototype that attempted to solve those coordination problems identified in practice. The case study focuses on the contemporary phenomenon of coordination for sharing knowledge, and the researcher had no control over the behavioral events of the study. According to Yin (2009), these conditions argue for the use of case study research. The choice for a case study is often based on opportunism, rather than on rational grounds (Yin, 2009).

The case study aims to understand how heritage experts get coordinated for sharing knowledge between heritage projects to abstract the particularities of coordination in inter-organizational and multidisciplinary knowledge networks. In addition, we also collect information about the match between coordination mechanisms and dependencies between task and we identified the coordination issues that experts have to face when they need to acquire knowledge from other heritage projects.

Accordingly, we proposed the following case study questions based on the actual line of inquiry in the case study.
1) First, “what are the object of study, organizational business and functions of the RedPHI? This question pointed out to identify and analyze the specifications of the RedPHI network in terms of analysis unit, collaboration, communication, coordination, knowledge management, knowledge sharing, basic functions, and its internal structure. This allows us to reach a deep understanding about how heritage experts from different universities, disciplines, locations, interests and ontological and epistemological approaches get coordinated to share knowledge about heritage projects.

2) After understanding the environment context, we try to identify “what are the coordination issues that affect the knowledge sharing performance between heritage projects?” through this question, we identify a set of coordination mechanisms and dependencies between activities that characterize the work in a heritage project inside the RedPHI. As an output of this question, a set of coordination issues were identified as affecting knowledge sharing at different levels in the RedPHI. These questions revealed the requirements and challenges that RedPHI meets.

- Thereafter, we also wanted to know “how information systems support or constraint the coordination activities for sharing knowledge in the RedPHI?” This question allows us to contrast evidence obtained in the two questions before about ICT-based coordination, as well as to identify empirical content to design an artifact that can address the coordination issues. According to our findings in the building of the knowledge base, we could map the coordination for sharing knowledge in the RedPHI with sociomateriality to identify to what extent, RedPHI benefits from the development of artifact designed from the sociomaterial approach.

The data collection in this case study included document analysis, interviews and direct observation in the fieldwork in order guarantee quality of findings via triangulation (Eisenhardt, 1989). Use of such multiple sources helped us to generate data rich in detail and rigor, providing better scope for triangulation (Miles & Huberman, 1994). We collected several documents including publications, technical reports, technical memos, videos, pictures, audio and video records, presentations, among other information. Constant access to the project content and updates were guaranteed in order to monitor what was going on in the heritage project through conversations and data for subsequent analysis. In addition, several interviews with heritage experts at RedPHI and native informants (people living within or around the heritage object) were held during the whole research. Information about knowledge sharing and information exchange between RedPHI researchers and other people was also informed during interviews and conversations. All formal interviews were recorded and transcribed and copious observational field notes were taken. Researchers visited the fieldwork taking advantage of willingness of heritage experts to share continuously their experiences, knowledge and documentation with researchers. In addition, researchers attended staff and group meetings, coffee conversations and phone calls with heritage experts. All data collected was related to creation and operation of RedPHI projects developed inside the case study and individual experiences of heritage experts. In addition, data was listed and saved in a database in order to ensure traceability of findings. Data analysis was carried out through structural codification process (Miles & Huberman, 1994), this process was tested in quality and functionality until reaching 90% of recode consistencies. Coding process were stopped when categories reached saturation. Case study analysis included
pattern-matching logic (Yin, 2009). In the rest of this chapter, the case study evidences are presented.

### 3.3 The organization

The setting for this case study was a knowledge transfer network about historic and cultural heritage. Specifically, a deep exploration of the Iberoamerican Historical Heritage Network – RedPHI were conducted. RedPHI was constituted in 2011 as an international and collaborative network leaded by seven universities from same number of countries (Argentina, Brazil, Chile, Colombia, Mexico, Spain and Portugal). The RedPHI is highly specialized in heritage projects that involves different activities over material heritage objects such as diagnosis, management, conservations, restoration, and maintenance, among others. RedPHI aims for protection and conservation of the cultural heritage through research and consultancy projects as well as education and divulagation of knowledge. RedPHI intends to manage and develop conservation projects in the architectural, urban and landscape scope. RedPHI has some particular characteristics, which make it a special setting for studying sociomaterial coordination for sharing knowledge. First, heritage projects involve heterogeneous actors that develop specialized activities. Heterogeneity means different disciplines, groups, institutions, networks, location, ontologies, and methods, among others. For instance, a heritage project can involve different disciplines such as architects, electric and chemical engineers, geologist, sociologist, anthropologist, economist, lawyers, among others, each one using a diverse and particular set of physical and digital materials in order to perform different project tasks in particular contexts and situations. In addition, heterogeneous actors exchange different types of information associated with multiple tasks and activities performed by individual or teams, which can be work in synchronous or asynchronous ways. Academic and professional information is mostly available in digital documents, but technical information is also available in physic form. Most of the documentary information corresponds to unstructured narrative text and in some cases semi-structured. These features are in line with current studies about the sociomaterial view of heritage practices (Harrison, 2016; Silvén, 2014).

Second, heritage projects involve a set of coordination issues for knowledge sharing (Nova & Gonzalez, 2016a) because the technological diversity for knowledge sharing affords people possibilities to use different technologies with different members, in different ways, and at different times, according to the context and situation dynamics. Thus, coordination for knowledge sharing in heritage projects is a process highly complex and dynamic because coordination mechanisms emerge during coordinating activities and so coordination cannot be a planned activity (Nova & Gonzalez, 2016b). Third, the RedPHI work approach demands a holistic treatment, because heritage objects are not only explored from its materiality but also its relation with the human being. In the last three decades, the ontological view of heritage objects as monument, which is based on environmentalist and geometric statements, has been substituted by a territorial approach focused on the “social character that contemplates the territory or space as an element not given, but constructed” (Ortega, 1998). Therefore, scholars have started to consider heritage as a sociomaterial entanglement where the territory concept enacts a relational notion that insinuates a set of links of dominion, power, belonging or appropriation between a portion or the totality of the geographical space and a certain individual or collective subject (Montañez & Viviescas, 2002). In this sense, territory is no longer considered as a direct or
indirect relation between entities (object-subject) with intrinsic properties, but it is an “indissoluble system of objects and systems of actions” (Santos, 1997).

Finally, three dimensions can be distinguished from the RedPHI scope: semiotic, contextual and physical dimensions. The semiotic dimension entails human and individual interpretation and appreciation for either researchers who investigate, protect, maintain and preserve the heritage object or heritage objects’ owners (when the object is private property) as well as people who take care of it. The contextual dimension reflects the value of the heritage object, abstracted from its context, analyzed jointly with their environment and observed as a part of a territory. The physical dimension represents their physic, material and tangible being. Therefore, the objective content jointly with the subjective attitude enact the features and understandings that characterize the heritage object from a territorial approach. Following this perspective, the set of dimensions are neither independent entities nor have inherent properties, but they are interrelated and so a heritage object can be understood as sociomaterial reality. Next, we expose the problem background at RedPHI.

3.4 Sociomateriability in heritage
As we posited in section 3.3, the work of RedPHI experts involves several characteristics that make this domain a special setting for studying sociomateriability (Harrison, 2016; Silvén, 2014). One of the main artifacts in a heritage project is a Special Plan for Managing and Protection (SPMP) of heritage objects. The SPMP is an instrument of planning, managing and funding that leads to the conservation of human memory and identity through the protection, conservation and sustainability of material and historical heritage objects (Mejía, 2010). The purpose of the SPMP is to define the short and long-term actions for capturing and transferring knowledge about heritage objects for future generations. The SPMP must represent the different dimensions in experiencing the territory (sociomaterial enactment that join communities and heritage objects), the different ways of experiencing culture and memory by inhabitants, as well as historical entanglements between the materiality of the object and the social agency enacted to protect it.

Each SPMP is tailored to particular characteristics of each object. Depending on content, context and perspectives, different kinds of materials related to the heritage object and its exploration may work as sociomaterail actors in the construction of identities, stereotypes, and power relations (Silvén, 2014). Materiality of each heritage object is unique, as well as the human perceptions about it. In this sense, each SPMP must gather the specific material features of the object such as building materials, morphology, fabrication techniques, volumetric features, utilities, among others; but also it must show cultural, human, historical, social, economic and political characteristics of inhabitants or people living around the heritage object (Therrien, 2009). This implies identifying and characterizing relationships between communities and heritage objects, how these relations have evolved historically and how this determines conservation and sustainability. Although materiality of the heritage object itself transcends variations in space and time, usage and actions are different depending upon the context in which the materiality is understood. In this sense, SPMPs must account for singularity in material and social agencies as well as in their current and historical imbrications. Therefore, understanding sociomateriability in heritage objects and translating insights into a SPMP, implies a particular
focus on sociomaterial and emergent practices and the happening of the social, all viewed from different backgrounds and expertise with a broad methodological toolbox (Harrison, 2016).

Even though each country defines what components a SPMP should include, and there are common aspects between countries and approaches, each heritage object claims a specific formulation. For instance, the Main Andean Road called “Qhapaq Ñan” is a heritage object shared for Argentina, Bolivia, Chile, Colombia, Ecuador and Peru, and it is part of the world heritage list protected by Unesco. Each country formulates its own SPMP (with different names but the same purpose) that leads to protect the specific area located inside the national border enacting the particular cultural and historical significance for the nation. However, a global SPMP that accounts for international treaties is necessary to nominate and then keep the object in the list. This example illustrates the fact that SPMPs are highly context-dependent and that the context may even have several levels of analysis, each one enacting a different plan.

The cornerstone of the exploration is to deeply get to know the conversations between materiality of the heritage object and human perceptions of it. Those conversations represent how material and social agencies has been historically imbricated and how the imbrications events have transformed the identity of a society. The goal of heritage experts is going through history to reconstruct the structure of the imbrications that lead to its prevailing situation, in order to compile a consistent view of the object value that can argue how important is to protect and conserve its materiality and the memory about historical and current sociomaterial relationships.

The current status of a heritage object is product of past imbrications, experiencing prior sociomaterial processes but also configuring new ones. Certainly, inhabitants or neighbors of the object determine how it is imbricated with social practices over time, and it is an ongoing process of imbrication that constitutes the sociomaterial identity of the object. Therefore, exploring imbrications in the heritage domain implies a deep corpus of knowledge (documents, pictures, architectural drawings, geolocation maps, laws, technical standards, interviews, field notes, etc.) that a team of heterogeneous experts (see section 3.3) must collect, share and process in order to identify sociomaterial practices over time. Consequently, the in-depth knowledge of the imbrications rests on accessing the overall information regarding the specific heritage object as we present in section 3.8.

3.5 An empirical illustration of sociomateriality in heritage work
To understand the imbrication metaphor in the domain of architectural heritage work, next we present an example of affordances in practice and their effect in the knowledge sharing process (Nova & Gonzalez, 2016b).

**Imbrication 1 – hose-based level to total station.** For many years, the hose-based level has been the common way to measure settlement displacements with a high level of accuracy using a simple tool. Two communicating vessels are interlinked with each other by means of a hose, which contains a liquid. The level of the liquid is read off by analogue means on a scale. Although the system is simple to use and can be easily adapted for different areas, some mistakes could arise due to water leaks or wrong water levels. Thus, the hose-based level tools have a margin of error
that can affect leveling studies in architectural heritage projects. The constraint explained above was leaded by the experts changing the hose-based level by a total station, which is a surveying equipment combination of electromagnetic distance measuring instrument and electronic theodolite. Experts interpreted total station ability to measure level digitally as affording them to reduce manual errors involved in reading and recording which affect considerably the technical process performed in a heritage project. Then, most of the architects and civil engineers started to use a total station tool in all architectural heritage projects in order to calculate with more accuracy the land level in a heritage object. The new work routine made the fieldwork activities less manual and encourage experts to take advantage of a new technology for improving quality in their heritage studies.

The use of the total station tool changed the work routine but at the same time generated new configurations to coordinate the knowledge sharing process. Based on the real time information produced by the team of four architects about design, measures, materials and state, data collected manually from the hose-based leveling was mostly sketched by the architect leader in paper and then the team got feedback with results. The set of architectural drawings enacted a coordination mechanism through which architects shared knowledge each other. The coordination mechanism was used to connect experience of architects and civil engineers with knowledge from other disciplines to complement or expand the heritage analysis. Based on the architectural drawings, sometimes it was necessary to hire additional experts i.e. topographer, so as to verify the field measures and confirm the survey results. Later, with the final version of the architectural drawing, the architects built a mockup (a 3D model elaborated manually) representing the current state of the object which afforded them to make decisions about the task sequence for the next stage project, usually the restoration activities. So making decisions during the whole process took a lot of time. Finally, the change in technology enacted another way to exchange information and share knowledge because data collected form the total station could be downloaded to computers for further processing and then it was possible to send file outputs by email or share it using cloud computing. Thus, using technological devices afford experts to share new findings easier than citing people in technical committees.

*Imbrication 2 – total station to 3D scanner.* Although total station allows experts to carry out activities faster than using the hose-based level, a new constraint was perceived by workers. Using total station does not permit to optimize the execution time required to measure by hand all the details that a specific study needs to represent. Thus, the architectural survey took a long time making the study inefficiently, whereby engineers had to rent additional tools affecting the budget of the project. It became clear to experts that total station constrained their ability to perform activities at the scheduled time. Consequently, architects and civil engineers stopped using total station and started to use 3D Scanner. Scanners automatically acquire a so-called ‘point cloud’ with a resolution determined by the surveyor before starting the scan. The clouds will then be connected to each other through the overlapping areas gathered from several different scanner points, using software that perform this type of calculation that is defined in jargon ‘cloud-to-cloud registration’. Accordingly, when experts began to use this new technology they found that the time spent for data capture in an architectural survey was reduce significantly and the diagnosis and restoration time stop was shorter. As an example, using a 3D scanner in the “Iglesia del Voto Nacional” enable experts to detect in one day a deviation in the position of the main...
religious images on the top of the dome, but using other techniques this diagnostic would had taken some weeks. Also, 3D scanners afford experts the ability to make deeper analysis of the object measures and there is no need to touch the measured object, which in some cases is not possible or desirable. Nowadays, experts use 3D scanners depending on the heritage objects complexity (access, physic state, availability) and as a way to save time.

Using total station afford the experts to change the method to collect data from manual to digital techniques, enabling them the use the CAD tools as AutoCAD. Now, the CAD design of the heritage object enact another coordination mechanism. A set of iterations for designing are necessary to get the digital architectural drawing of a heritage object. Consequently, it is necessary to exchange information not only between architects, but also with the CAD expert for preparing digital lay-outs and sketches and determine design elements for various structures and building components. The skill of drawing has been lost by the architect and now is assumed by the digital design specialist who is considered as another expert. In the technical committees, people engage easier viewing the 3D model than the architectural drawing in paper, and urgent decisions can be made faster whit the later. Using the 3D scanner, the need for drawing in AutoCAD is reduced because the model is already built in less than thirty minutes and using plugins the software is able to synchronize file outputs with others applications and devices like 3D printers, thus, architects no longer need to build mockups to make decisions because the 3D printer build it faster. Based on 3D models, experts can prioritize tasks and budgeting from first aid interventions to additional details that can be omitted without affecting the final result, and this allows experts to rescue the heritage object, like a patient in an emergency room. Finally, the change in technology enact another way to make decisions emphasizing the importance of the digital design rather than the physical object.

Imbrication 3a – 3D scanner to virtual reality. 3D scanner affords experts many possibilities in order to capture information from complex objects, however 3D scanners do not afford experts to get information from inside of walls, roofs, support beams and others materials of the structure which is very important to detect water, drainage or electricity networks as well as gas connections. Experts perceive this as constraint because they had to use additional tools like radar detectors or x-ray scanners which afford them to explore internal conditions of the object structure making the tests less invasive than 20 years ago when experts must break the wall to perform vulnerability studies. However, post processing the point cloud is another constraint, because there is enormous work for manipulating and filtering many points in order to get useable information before transporting this data into a 3D model. Although most of the software platforms have combined algorithms for triangulation and surfacing of the point cloud, manipulating and filtering data require long time as well as specialized knowledge about how to edit the point cloud. Thus, a new change in technologies has occurred in the heritage domain. By using virtual reality, experts and people in general can perceive the third dimension and the “virtual investigation” of the object become more realistic. Experts argue that this can be a simpler, natural and correct way to analyze and present information reducing the possibility to make evaluation mistakes due to the false prospective of the classic visualization trough hose-based level, total stations and even 3D scanners. So virtual reality can afford experts and non-experts visualizing in only one tool all the technical information like drawings, topographic studies, material specifications, pathological studies, etc., but also can offer information to
students, teachers, researchers, majors, specialists, entities, enthusiastic people, and others about
history, evolution, transformation, representation, projects performed, cultural expressions, and
all kind of information linked to territorial studies.

**Imbrication 3b – 3D scanner to total station.** The 3D scanner affords experts to make more
productive their work with high information quality and allowing them the possibility to represent
the space detected in an innovative way different to the traditional 2D. File outputs from a scanner
can be processed using diverse CAD tools producing complex and well elaborated models. Many
 technological tools can be used under a license code for University membership which they keep
updated in order to teach students how to use this tools in the real life. However, most of the
governmental customers (ministry, secretaries and institutes regarding heritage domain) prefers
to analyze the traditional file outputs in 2D and physical drawings rather than 3D models because
they do not have technological capabilities to process and analyze it. Consequently, governmental
entities consider 3D models as complementary information because for many years they have
made decisions without it, moreover bidding conditions include mandatory to submit the
architectural drawing in paper. Thus, customer rules and governmental limitations constraint the
possibility to take advantage of the digital tools for an architectural survey, but also they delay the
implementation of technological advances that affords many action possibilities for supporting
world and national heritage declaratory activities. Additionally, this factors limit the proactive
efforts of surveying firms with scanning capabilities. As an effect of this constraint, at the time
experts want to participate in a project financed by governmental entities, they have to change
their work routine from using high-end technology to using a total station tool, in order to
accomplish tasks in the terms demanded by the bidding conditions.

By following the prior example, we present some insights that contribute to the design cycle.
Details of this insights can be found in (Nova & Gonzalez, 2016b). Imbrications 1, 2 and 3a support
the findings by Leonardi (2011) abut sequences of imbrications that happen by perception of
constraints, causing changes in technologies and perception of affordances, producing changes in
routines. Affordances perceived from technology are mainly context-dependent so coordination
mechanisms can be adjusted or even replaced to produce better performance in the project tasks,
which in turn implies a transformation of the knowledge sharing practices. Additionally,
sociomaterial relationships also depend on interconnection between sociomaterial networks of
actors participating in the same architectural heritage project. In this sense, it is possible to
 modify coordination when heritage experts perceive an affordance or constraint from their own
sociomaterial ecosystem, but can also be adjusted according to the ‘realm of structure’ of an
external organization involved in the same project they are working on.

It also shows that imbrications can go back and forth as perception of constraints is temporary.
Leonardi’s perspective of imbrications supports the idea about recursive interaction of social and
material agencies over time. Actually, time is one aspect that Leonardi claims as distinguishing
between critical realism and agential realism (Leonardi, 2013). In this sense, interaction between
realms of structure and action seems to always go forward, and imbrications that return the
organization to a previous point should be considered as a new imbrication that moves forward.
As imbrications constantly produce changes in routines and technologies, agencies can be
disentangled, reconfigured and entangled following previous imbrications and according to particular requirements.

Additionally, alternative imbrications are possible for the same technological affordance; in the coordination domain, they enact a dynamic and emergent process guided by ubiquitous and pervasive technology available for all actors. This means that flexibility, autonomy and serendipity in configuring the personal and team sociomaterial ecosystem are a fundamental basis to design a knowledge sharing system.

### 3.6 The knowledge sharing environment of RedPHI

In the RedPHI project, the knowledge sharing process between projects performed by different heterogeneous groups has become difficult. Coordination is increasingly problematic for enabling people to learn from other projects and to share their knowledge in heterogeneous spaces. Many difficulties arise when experts from different disciplines, institutions, groups, backgrounds, and ontological and epistemological perspectives try to exchange information and share knowledge with other people. However, difficulties increase mainly because experts are likely to use different tools and technologies with different members of their project or even between different projects. One architect expert in heritage projects uses a set of communication technologies every day that another expert architect probably does not use frequently. A group of architects can share tools that lawyers do not use. Pontifical Xavierian University (PUJ) experts with different backgrounds, due to the kinds of common computer systems, applications, and networks their department or institution has adopted, are likely to use the same technologies and common tools. Collaborators at Polytechnic University of Madrid are less likely to be as comfortable using these tools, if they do not use them routinely at their own institution. As the literature in sociomateriality as well as the RedPHI case study showed, instead of a common suite of software for the entire project (RedPHI platform), heritage experts are likely to adopt and use technology with each other in familiar ways. Because there is a huge portfolio of technology-based coordination mechanisms, this diversity is a major challenge for sharing knowledge.

Based on this heterogeneity, learning from other heritage projects and making fast and efficient decisions based on this knowledge is difficult. Making decisions based on good and bad experiences is challenging when knowledge based on lessons learned is fragmented in different personal technologies but it is even more problematic when people do not share the same tool to manage it. Nevertheless, technology use itself is not the problem. Acquiring knowledge from other projects and using it in practice depends on how people interact with technology and this is a sociomaterial issue. Therefore, instead of transferring knowledge as an object from a source to a receptor, we claim the knowledge sharing process in the RedPHI occurs between projects because a project enacts different and diverse relationships between heterogeneous experts and a set of materials they configure in dynamic and emergent ways to pursue a specific goal in a particular context. Thus, the research gap is how to improve the coordination between heritage projects composed of different individual ecosystems that need to be coordinated to enable knowledge sharing seamlessly between heritage experts. We do not focus on knowledge transfer between heterogeneous experts in the same team. Instead, our focus is on sharing knowledge between projects performed by different teams belonging to distinct institutions. Therefore, we want to see
how knowledge about managing heritage projects is shared with other RedPHI members and how the PUJ can learn new knowledge from heritage expert’s teams of those institutions.

The heritage domain has two interesting features, which make it a special case for studying coordination in knowledge sharing activities following a sociomaterial perspective. First, there is a progressive transition in the conceptualization of cultural and historical heritage that leads from aesthetic considerations enacted in singular and exceptional art related to nature, towards the concept of territorial heritage, which embodies a sociomaterial essence. In this transition, there has been a gradual reunion of the natural and the human, which have been separated in natural heritage and historical heritage, identifying the last one as built heritage. The key point is that there is a perceptible evolution from the aesthetic to new dimensions such as social and natural sciences, and from the singular and exceptional towards a holistic and open perspective. This brings both an ontological and epistemological change in the way the heritage objects are explored and operational and methodological variations due to openness to distinct conceptual viewpoints. In this movement, the common heritage perspective based on physical materiality is mixed with, and at best, it becomes a sub product of the quotidian activities. Accordingly, the territorial approach discovers a dimension of the society that has built the aesthetic aspects and at the same time, it has been drawn from them. Sociomaterial considerations of territory provide, therefore, a corpus of knowledge about their use, the projective task itself, the challenge to which it responds and the living conditions in which it has been utilized.

Second, this evolution matches with the coinciding transformation of the sociotechnical view of information systems. It shares a similar transition from focusing on humans and technologies as discrete entities or mutually dependent that interact temporally and then get separated, towards examining how materiality is intrinsic to everyday activities and relations. In this sense, the transition enacts an ontological change in the way we consider relations between humans and technologies, from using an ontology of separateness that considers technology and humans as essentially different and separate realities to considering a relational ontology that presumes the social and the technological elements are inherently inseparable, play equivalent roles in a network of relations, and do not express inherent characteristics by themselves. In this transition, focusing on the impacts, implementation or uses of technology masks how people and technology are reciprocally inter-defined as people interact with technology in everyday practices. The inter-definition depends on whether people perceive that a technology affords or constrains their goals. From this sociomaterial perspective, people perceive many possibilities for action from technology, and these affordances can lead them to realize new intentions for coordination in knowledge sharing activities.

What we realized in the RedPHI case study is that not all the RedPHI members manage the heritage projects using the territorial approach because it implies a common understanding between different disciplines, out of the scope of architecture, which has been the predominant discipline in the heritage domain. The disciplinary diversity naturally has conceptual differences to explore heritage objects and this increase considerably complexity at both operational and methodological levels. In this sense, the ontological and epistemological differences between inter-institutional research groups and even within the same research team performing a heritage project, affects collaboration and coordination and so represent a barrier for sharing knowledge
between projects effectively. In addition, as we posited before not all RedPHI members use the same tools and even using the same tool they use it in different ways because they perceive different affordances from the same artifact. This occurs for both technical materials such as hose level meters and architectural drawings, and coordination mechanisms for sharing knowledge such as cloud computing services and instant messaging applications. Here, heterogeneity increase complexity at the time people need to reach coordination for sharing knowledge.

Consequently, the knowledge sharing performance depends on how experts can overcome the ontological and epistemological differences using information technologies as a mediator in dynamic and changing environments. In this sense, the purpose is to enable coordination for sharing information and lessons learned in distributed projects overcoming tensions and barriers from heterogeneity aspects. In doing so, technology-based coordination mechanisms play an important role to foster collaboration between experts and knowledge sharing between projects because they can promote collaborative thinking, calling the collective wisdom into full play. The challenge is to bring together all kinds of knowledge and views of heterogeneous RedPHI members in collaborative groups can promotes the cooperation and knowledge sharing between them. Therefore, coordination can serve as a bridge, linking not only experts, but also professional groups and projects supported by different backgrounds.

However, sharing knowledge about heritage projects is not a specific challenge of the RedPHI members. Within the Colombian context there is many knowledge-sharing issues regarding to heritage projects. For instance, mayors in small towns frequently face diverse technical and administrative problems about managing heritage objects such as ruins, buildings and landscapes. Commonly, managing heritage objects requires a highly specialized knowledge, which often is not available and easily accessible for everyone, so that mayors have to make decisions based on assumptions or even to steer away from intervening the heritage object. Although the Ministry of Culture has a web service with laws, procedures, guidelines and rules to protect and manage the heritage objects, this information is not easily comprehensible. Therefore, making decisions about a heritage intervention without the specific knowledge required for that, without reference projects from similar contexts, and without access to specialized guidance from heritage experts is highly risky because it can end in failure of interventions that can affect the unique materiality of the heritage object presently being studied.

Knowledge sharing issues are faced partially by expert universities in the heritage domain. Universities perform many academic, research and consultancy projects producing a huge diversity of useful knowledge for many activities such as guiding majors, owners and enthusiasts in heritage activities, promoting public policies for managing heritage projects with novel perspectives and supporting management activities in individual settings including small towns, religious communities and private customers, among others. However, the knowledge sharing process between projects performed by universities and projects developed by national authorities is narrow due to technological and administrative barriers, which limit coordination between experts and reduce availability and access to information and knowledge. Consequently, the knowledge sharing process between heritage projects is problematic for both the RedPHI case study and the individual context of each university.
3.7 Specific barriers for knowledge sharing in the heritage domain.

In this section, we present a summary of the specific problems for sharing knowledge in the RedPHI. We illustrate the requirements and the effects (design dimension) they should evoke which will be analyzed and abstracted as meta-requirements for KMS designing activities in the next chapter.

Collaboration and coordination for sharing knowledge between heritage projects is inefficient for several reasons. First, access restrictions to prior knowledge about a heritage project limits the possibility to reuse knowledge to perform a new task. Although each heritage object embodies unique material properties and the characteristics of the management process is highly specific, some elaborations for a specific project such as intervention methods, diagnostic outcomes, material references, restauration techniques, et., could be used for managing other objects in the same category or with similar materiality. However, instead of making deep explorations and analysis based on the available knowledge, frequently heritage experts repeat the same activities that were conducted before in other projects and so reinventing the wheel is a common issue for sharing knowledge. This problem is also related to lack of feedback between experts and actors involved in the project. For instance, experts often receive information from communities and national institutions in order to perform research activities within a project, nevertheless, once the project has finished, those actors do not receive feedback or at best, they receive a common divulgation product such as a paper or a book chapter, which they do not understand easily. For this reason, people reject to collaborate in future interventions, do not provide access to new information or keep mistrust during their participation.

Second, because the traditional perspective for exploring heritage objects has been based for long in the monumental perspective, currently there is still a conservative thinking that puts up barriers for collaboration and sharing knowledge between projects. However, this inertial understanding does not only concern knowledge sharing between projects but also between communities that live on/around or protect the heritage object as well as national authorities that are responsible for the object conservation. Therefore, the knowledge sharing issues are also a consequence of deep-rooted long-term trends, which are not easily changeable. Nevertheless, the purpose is not to make people understand the heritage object in the same way because it is impossible due to natural divergent thinking, so the challenge is to enable collaboration and knowledge sharing in the middle of this diversity of thoughts. In addition, it is a mistake to use the same strategy to increase the knowledge sharing performance when heterogeneity indicates that this process would be dynamic and contextualized. Communities, national authorities, experts and non-experts, enthusiasts, etc., enact different social settings that performs different everyday practices and so they can enact different knowledge sharing accomplishments.

Third, Technological diversity can help to overcome coordination barriers to exchange information in centralized or decentralized project settings, but authority and linearity in this activity affects the knowledge sharing performance. The scope of collaboration in a heritage project is defined by the project leader who determines the openness level to exchange information with others within or outside the project boundaries. The project leader does or does not allow the knowledge sharing activities putting restrictions or making completely open the collaborative space. But this behavior also depends on leadership styles, because in the RedPHI
case study some leaders incentivize collaboration and knowledge sharing between projects, but others, mainly guided by hierarchical systems, use a manufacturing approach in which an expert produces an outcome which in turn is an input for the next activity. This linearity in the information exchange downplays considerably the knowledge sharing activities because the leader is the only expert that can get the whole picture of a project and so, experts from other projects do not acquire contingent knowledge that can produce novel insights for the entire project.

Complementary, information completeness is not enough to promote knowledge sharing process between heritage projects. Even though the concept of territory has been highly promoted in the heritage domain, there is still a lack of understanding in both experts and non-experts communities about new sociomaterial considerations of heritage objects far from considering aesthetic properties. This barrier makes it difficult to obtain information in the heritage domain because it often implies to get access to historical records and willingness to share personal experiences and relationships with other people and materials. Sometimes willingness not only depends on individual decisions but also depends exclusively on a mediator who can facilitate partial or total access to physical materials interceding with all the concerned parties to openly discuss experiences. However, information problems arise when there is no a mediator in the project or the mediator is not available permanently and so the information is received out of the project milestones. In this case, the knowledge sharing performance is constrained by limited information availability and asynchronous information exchange.

In addition, the knowledge sharing process is very difficult when information is fragmented in many chunks, each one owned and controlled by different people. Information frequently is stored and shielded in such a way that opening and sharing is banned. When knowledge depends on specific people or materials and there is no a systematic management process it is difficult to create a corpus of knowledge about heritage objects that can be used as a reference for future projects and so the knowledge sharing performance is likely to decrease. Frequently, fragmented information can be understood in many ways, admitting distinct interpretations or having an incomplete picture so that ambiguity can also affect the knowledge sharing process. Heritage experts use many technological tools for sharing knowledge enabling communication, information exchange, discussion, among other material properties, but they end up being used as information repositories of personal use hardly for access to other team members or experts from other projects. This problem increases the complexity of knowledge sharing activities because people – experts and non-experts, have to perform many queries in different sources to determine whether information is available, complete and sufficient to supply knowledge needs in a project. But, when access is possible, there is no traceability of how shared information was used in practice by internal and external experts and whether new insights emerged by its use.

Another barrier for sharing knowledge between heritage projects is the lack of technological support to bring people together into project teams according to conceptual project’s needs. As we posited before, the territorial approach implies a natural movement towards multidisciplinary work. However, in some projects funded by national authorities it is mandatory to include some disciplines such as anthropologists or sociologists to perform very specialized tasks within the project, even if the ontological perspective of the Ministry is based on the aesthetic view.
Interdisciplinary work is not a problem itself, but the more specialized profile required, the more difficult to find some expert to do it. Even though awareness of who knows what is not always sufficient for effective knowledge sharing processes in heritage projects, it is the first and main step to connect people according to knowledge needs. However, technology does not offer enough support to identify alternative views and useful disciplines to develop a project as well as people who can eventually collaborate in the project.

The knowledge visualization also makes it difficult the knowledge sharing process in the heritage domain. The common way to disseminate projects insights is using the traditional academy media such as papers, book chapters, and books. However, this strategy assumes that everybody (rural communities, public officials, experts, enthusiasts, professors, etc.) acquires knowledge uniformly and they are interested in the same things, and so the project information is presented in the same way, with the same detail and content levels, omitting contextual variables that lead to effectiveness in knowledge sharing activities. Consequently, this strategy does not convey the essence of the heritage project because all the people related to the heritage project has no the same access to knowledge, identical ability to find the paper they need, equal mental model to interpret the information in the same way and equivalent ability to understand complexity of the content. In this sense, filtering information according to who is looking for it in order to reduce cognitive overload and irrelevance; helping to create meta-knowledge to support knowledge searching activities; and making knowledge visualization dynamic and contextualized are some weakness in the current knowledge sharing systems.

Finally, making decisions at different levels is challenging in knowledge sharing process between heritage projects. First, interdisciplinary work requires consensus in order to move the project forward as fast as possible. Consensus is achieved through negotiation concealing differences between radical positions, but most of the times, the project leader makes decisions alone using an authoritarian line and leaving individual positions on the sidelines. Therefore, making decisions without the whole picture of the project takes more time and is more risky. Second, national and local authorities in the heritage domain have to make decisions about permissions, characteristics, and refusals in managing heritage projects. This process takes a long time because the decision makers normally do not have complete information and knowledge about the heritage object and so problems are not easily visualized. Although the project enacts deep knowledge about the heritage object, authorities are interested mainly in the final recommendations such as do or do not built, how many floors, which technical standards must the experts accomplish, etc. But even though their focus is on the project outcomes they also need a basic knowledge to support the decisions taken. Third, making decisions based on previous projects depends on availability of the project leader. Most of the information about a specific project phase is owned or controlled by the consultancy or research leader and so if the project team changes, it is hard to use previous knowledge beyond the information available in digital or physical materials received by the contracting part. It is also a common barrier when experts try to get knowledge from other teams in other universities. For instance, the RedPHI platform contains a structured template to share detailed information about a heritage object; however, it is still unused in the PUJ because this information is considered just as data, which does not represent sociomaterial meaning. According to the heritage experts, the cornerstone of the knowledge sharing process between projects is to share not just data and scientific analysis of
materiality but also the sensations obtained during the project development process, because the
two are contingent and complementary in the territorial approach, and both elements enact the
sociomaterial foundations of the heritage domain.

3.8 Specific requirements

Knowledge access
The first issue that the exploratory case study revealed (see Chapter 3) was the access to
knowledge about heritage projects in a knowledge sharing network. Full accessibility to project
insights and lessons learned database for all experts and non-experts is crucial to leverage
knowledge sharing practices between heritage projects. Having an open and accessible knowledge
base to perform a new task can lead to actually effective utilization of that knowledge in new
projects. Timely access to project knowledge can facilitate reuse of prior insights and personal
experiences to solve novel issues as well as can enable making decisions in new project settings.
This can be translated into the following requirement:

Requirement #1: the KMS for heritage projects should enable access to project insights during
and after the project life-cycle affording reuse of knowledge.

People access
In the heritage domain, we can infer that access to other people’s thinking is critical and it is likely
a real trigger to foster collaboration. People access might also be thought of as a relational variable
not entirely based on physical closeness. Awareness of experts’ relevant expertise and being able
to gain timely access to that person is important to increase social capital in the heritage domain.
In this sense, facilitating network connections between heritage experts mainly aims to create new
knowledge based on shared representations, interpretations, and ontological matching among
parties. However, social ties are not only important for current projects and experts in a specific
context, but also, they represent relationships that may be used in other contexts for other people,
such as researchers, students, public officials, majors, etc. Hence, the KMS should enable heritage
experts to search for project insights and to enable collaboration via indirect search of knowledge
by contacting other experts. This can be translated into the following requirement:

Requirement #2: the KMS for heritage projects should facilitate access to both experts and
expertise to exploit network knowledge opportunities.

Centralization
The case study also revealed an unsystematic disposition of knowledge about heritage projects in
different repositories. Knowledge about heritage projects is stored in a diverse set of technologies
such as digital and physical institutional repositories, personal cloud services, institutional web
services of different areas (faculty, research board, library, program web service, etc.), among
others. Therefore, the implementation of an adequate central storage medium adapted to the
specific project needs and their participants is a vital necessity. Searching and retrieval
functionalities are key points to facilitate reusing of knowledge available and distributed in many
artifacts. This can lead to build up a corpus of knowledge about heritage project insights than can
be accessed easily by experts and non-experts actors at any time and location. This can be translated into the following requirement:

**Requirement #3:** the KMS for heritage projects should allow to connect different knowledge repositories in a central storage medium affording a corpus of knowledge easily accessible and usable in different projects.

**Knowledge retrieval**

Knowledge sharing networks also claim for completeness of information about heritage projects. In addition to having a central storage, it is also important to reach the whole information that a project team needs to perform an activity. Possibility to store information using indexing, categorizing, tagging or clustering could facilitate further searching and retrieval of knowledge. The completeness of project information may vary from project to project due to individual settings. The more complete a specific type of project information, the more reliable experts can expect the results to be. Once the project task achieves a certain state of completeness, the expert assesses it and make further decisions. These decisions can be fully argued based on complete information or keep certain level of ambiguity due to underlying assumptions behind decisions. This can be translated into the following requirement:

**Requirement #4:** the KMS for heritage projects should support experts to complete the information needed to perform project tasks and make decisions effectively.

**Controlled access**

Experts in the heritage domain claim for a possibility to facilitate knowledge sharing practices controlling who has access to what in order to make open the knowledge available for all the people, but also restricting access to private information. This is commonly done by the project leader who acts as a regulator of the knowledge sharing process within or between projects. A heritage project follows a loosely coupled workflow process and there are certain kind of knowledge that is not relevant for specific tasks (i.e. anthropology studies barely connect with electrical engineering analysis) but most of the specialties are highly coupled to one another (i.e. architecture, archeology and restoration). Therefore, experts claim for a way to control access to project information according to project needs, which in turn can be an indirect manner to avoid cognitive and information overload for knowledge seekers. This can be translated into the following requirement:

**Requirement #5:** the KMS for heritage projects should allow different access level to project information enabling to share relevant knowledge according to project needs.

**Flexibility**

One of the most important claims of heritage experts is that existing KMS attempt to standardize the knowledge about a heritage objects using metadata. However, this presupposes that all heritage objects can be characterized in the same way and that all experts use the same mental model, methodology and strategy to explore, understand, evaluate and restore the heritage object. As many ontological and epistemological differences exist between experts, project teams, research groups, institutions, countries, etc., regarding to activities to investigate heritage objects,
both the project configuration and content are completely different within and between projects. In addition, a heritage expert can play simultaneous roles such as contractor, consultant, professor and researcher, so that in each role the project information can be stored, structured, organized and managed in different ways, and experts need to move easily and frequently from one project to other. In this sense, experts claim for flexibility to adapt the KMS functions to the project specifications and not vice versa. This can be translated into the following requirement:

**Requirement #6:** the KMS for heritage projects should allow a dynamic and flexible organization and structure of the information according to particular project settings and specifications.

**Knowledge visualization**
An additional issue the exploratory case study revealed was that knowledge visualization needs to be customized to the cognitive background of people (experts and non-experts). An adequate visualization of knowledge about heritage projects requires to identify the target group and the context among experts, research groups, institutions or networks of experts. Determining what knowledge is relevant for each actor and how to display knowledge to heterogeneous actors in an easily understandable way is a major undertaking. Offering different visualization options according to diverse understanding capabilities is crucial for facilitating an appropriate learning. Complementary, visualization should be fitted according to people needs because not all the resources and connections can be useful every time and, in every task, so it is important to filter information to be visualized in order to avoid cognitive overload. Therefore, the KMS should include a flexible visualization architecture to allow personalized changes in the structure and representation of knowledge.

**Requirement #7:** the KMS for heritage projects should offer different knowledge visualization options enabling customized connection with the already available knowledge.

**Decision making**
The case study also revealed that having access to knowledge is important to leverage sharing and learning practices but also usefulness of this aspects is about how people use that knowledge to make decisions in practice. There are different decision levels depending on who the decision maker is and the purpose of the decision. Heritage experts claim for a way to optimize the decision-making process through access to whole knowledge resources they need to make more informed choices. Backup, traceability and updating can help experts to make effective conclusions identifying decision alternatives. Feedback from prior decisions is also useful to reach effectiveness in project tasks but also for supporting future decisions. This can be translated into the following requirement:

**Requirement #8:** the KMS for heritage projects should help experts make informed decisions by making available all project knowledge resources.

**3.9 Evaluation of the case study findings**
In order to confront validity of the qualitative case study in this chapter and to ensure the correctness in our understanding of RedPHI’s situation and the generality of the findings, two
strategies to evaluate the results of case study were performed: triangulation and getting feedback from informants (Miles & Huberman, 1994). Triangulation is defined as “the combination of methodologies in the study of the same phenomenon” (Denzin, 1978, pp. 297–307). Triangulation allows ensuring the basic quality of the data. The primary purpose of using triangulation is to reduce biases and increase the reliability and validity of the case study (Denzin, 1978; Miles & Huberman, 1994). According to Denzin (1978) there are four types of triangulation such as by data source, method, researcher and theories. In this study, we performed triangulation by data source and by method. Triangulation by data source means collect data from different sources while triangulation by method means to use different collection strategies. The data corpus was composed by several interviews with RedPHI experts at distinct moments of the case study, in different places (head office and in-situ) with different unit of analysis (coordination issues, knowledge sharing barriers, specific requirements) and different levels of depth (general coordination issues or specific issues for consultancy or research projects, etc.). In addition to collect different data source to identify and validate the problem of this research and its specifications, different data collection methods were used to increase reliability when contrasting findings within sources.

The preferred method to evaluate findings was individual and group interviews with different RedPHI members and it was mainly because people were always willing to collaborate with this dissertation by suppling all kind of information necessary to explore, analyze and contrast case study insights. A large amount of physical and digital documentation (technical information, administrative reports, emails, proposals, projects compendium, etc.) about the principal projects at that moment (Restoration of the San Ignacio Church; Analyzing Territory, Violence and Resilience of Agua de Dios; Factory of fine pottery in Bogotá; among others) were used to triangulate insights from interviews. Finally, direct observations in the field study were conducted in two of the projects mentioned. Field notes, pictures, recordings, videos and information gathered in-situ was important to verify most of the findings identified during interviews and project documentation analysis. In summary, triangulation supported findings about the identification of coordination mechanisms and interdependencies between activities in heritage projects, coordination issues for knowledge sharing, specific barriers for knowledge sharing in the heritage domain, and mainly the elicitation of the specific requirements.

To ensure the internal validity of the RedPHI situation, we invited experts to evaluate the results of case study. Getting feedback from heritage experts supports verification of findings with who supplied the original data (Miles & Huberman, 1994). The findings of this case study were presented in two sessions to heritage experts from RedPHI. The presentation aimed at collecting feedback from the audience about the correctness of the understanding of the RedPHI context and the verification of the case study findings. The feedback shows that the understanding of the particularities, issues and barriers of coordination for knowledge sharing at the RedPHI network, and also the challenges from the heritage context are complete and correct. Furthermore, the heritage experts from RedPHI confirmed that several coordination issues emerge due to diversity and non-patterned use of coordination mechanisms involved in the heritage projects. Completeness and correctness of specific requirements were specially verified during additional interview sessions with heritage experts. Experts confirmed the formalization of the requirements and proved the reliability and acceptance of those abstractions from the RedPHI.
Besides reporting and communicating the case study with experts from the application domain, we also presented the case study to the academia at the 8th International Conference on Knowledge Management and Information Sharing (KMIS 2016) (Nova & Gonzalez, 2016a). An extension of this case study was also published in the Lecture Notes in Computer Science (LNCS) (Nova & Gonzalez, 2016b).

3.10 Summary
The objective of this chapter was to identify the organizational and technical factors influencing the coordination design process for knowledge sharing activities between heritage projects, in line with the second research question. In doing so, we conducted the single case study of the RedPHI to understand the empirical environment of an interorganizational and multidisciplinary knowledge network. Besides, we applied the findings from the study on the concepts of coordination, knowledge sharing and sociomateriality in the context of RedPHI projects, exploring and understanding how coordination takes place when heritage experts have to share knowledge in different settings. Outcomes from the exploration are used in the design and evaluation of the reference architecture and the corresponding instantiation.

By identifying interdependencies and coordination mechanisms, some coordination issues were revealed and specific requirements were gathered. Coordination issues are not associated to the mechanisms per se, but with the situated and contextualized selection of coordination mechanisms within a large portfolio that lead to different sharing barriers. Heterogeneity is one of the main challenges that IS designers must address to design effective KMS as a large variety of human, material and social agencies rise complexity in coordination activities. The overall coordination activities rest and depend on different contextual dimensions. Every combination of agencies and context leads to several coordination possibilities and knowledge sharing alternatives which are difficult to convert in patterns. All these findings support prior findings about dynamic and emergent coordination and guide the research focus towards sociomaterial inquiries, which suggest that all coordination practices are always configured by some specific sociomateriality, and thus for studying coordination in the knowledge sharing process, we should study sociomaterial (re)configurations as coordination activities are performed in practice.

Grounding on findings from literature review in Chapter 2 and empirical findings gained in Chapter 3, we developed enough inputs to design and evaluate the reference architecture presented in Chapter 4 and the KMS prototype in Chapter 5.
4 A REFERENCE ARCHITECTURE FOR SOCIOMATERIAL DESIGN

This chapter and chapter 6 report on the design cycle of our design science research framework. This cycle integrates the findings from the rigor cycle (Chapter 3) and relevance cycle (Chapter 4) to build the artifacts in our research. In this chapter the design artifact, namely, the reference architecture consisting of a set of design guidelines is presented to answer the third research question. Chapter 6 presents a prototype of the design architecture for testing whether the implementation of the design architecture can improve the coordination process in knowledge sharing activities.

This chapter is structured as follows. We first summarize the sociomaterial process carried out to identify design requirements and formulate design guidelines. Later, we show the architecture scope and requirements that we learned from the literature review and case study. Then we elaborate the design guidelines as fundamentals for the reference architecture by KMS designers. Thereafter we describe the system structure and components for involving research project management, visualization tools and augmented reality. Finally, we evaluate the reference architecture with both expert reviews and simulation.

4.1 A sociomaterial process to identify design requirements and formulate design guidelines

The sociomaterial process to identify design requirements and formulate design guidelines is grounded on the idea of that the design process itself enacts several conversations, imbrications, and trading zones at different levels and scenarios. Each step performed during the design process involved an ongoing configuration and reconfiguration of several materials (physical and digital), people (heritage experts, technology designers, researchers), and contextual dimensions in which people perceived different affordances and constraints. By understanding those elements as ontologically and analytically separated (see Section 2.5) and grounded on a critical realist view (see Section 1.5.1), it was possible to analyze their interaction as ongoing imbrications. Observation and analysis of conversations between material and social agencies took place when, for example, communities of experts explore objects in practice, heritage experts and technology designers participated in design workshops, the author of this dissertation built the KMS prototype, but also when technologies composing the KMS where connected, and so on.

In the design process, high-order imbrications took place when designing the sociomaterial design process for KMS. However, fundamental sociomaterial imbrications also occurred when designing the KMS. Therefore, we conducted a sociomaterial design process (procedural steps presented later in this section) involving both the heritage domain and the IS design domain in order to formulate a sociomaterial design process (design requirements and design guidelines) for KMS. This means that our reference architecture is sociomaterial by nature because it was developed by performing a sociomaterial design process, but also because the main artifact (design guidelines) attempts to lead IS designers in the sociomaterial design of KMS, which can be configured and reconfigured by heritage experts in a sociomaterial way.
By understanding how human and material agencies are enrolled in webs of sociomaterial negotiations that constitute the design process and the artefact, it is possible to learn about sociomaterial design, constituting spaces, trajectories and relationships for the IS design. In Leonardi and Rodriguez (2012) words, the possibility for KMS design rests on the recognition and understanding of sociomaterial practices as imbricated, and on the designers’ ability to identify which imbrications are configured but also recognizing which ones can be dismounted and reconstituted without causing the entire sociomaterial ecosystem of individuals and groups to collapse.

Based on an abstraction from the RedPHI case study and the literature review about sociomateriality, and underpinned by implementation guidelines for eliciting design requirements through a sociomaterial lens in design guideline 3 (Section 4.4.3), we derive design requirements. Our understanding of the coordination process for sharing knowledge (see Chapter 3) enabled us to abstract the common knowledge sharing practices of collaborative and heterogeneous work teams. Our literature study allows us to analyze the common coordination issues for sharing knowledge in heterogeneous work teams, and extract and synthesize them in a set of requirements on our reference architecture. The implementation guidelines allow designers to explore quotidian activities of heritage experts and observe the broader sociomaterial ecosystems in the heritage work of RedPHI. The main objective of this process was to explore conversations between knowledge sharing traditions, in the first place, but also between people, between people and technologies and among technologies themselves.

In doing so, we carried out several activities along the entire exploration of the RedPHI case study. We started knowing details about the heritage domain and work, identifying and characterizing interactions between sociomaterial ecosystems and then looking into them in order to explore conversations, affordances, constraints, and imbrications when experts get coordinated for sharing knowledge. At this point, we used a people/dependencies/mechanisms framework because it enacts a critical realist view that is coherent with our sociomaterial perspective of separation between heritage experts and coordination mechanisms as they have inherent properties that appear to become inseparable when a dependency occurs. The process to identify the design requirements is presented in steps 1 to 6.

Once design requirements were identified, an iterative process of design and evaluation was performed in order to formulate the design guidelines for KMS from sociomateriality. At this point, the overall insights gathered from the RedPHI case study and our theoretical and philosophical understanding of sociomateriality, were joined together in order to build the design guidelines as a design artefact that aims to solve the research problem stated in section 1.4. In doing so, a collaboration engineering process was designed and developed, in order to formulate the preliminary version of the design guidelines for KMS from sociomateriality. Then, we joined the preliminary version of the artefact with applicable knowledge grounded in literature about information systems design. Through multiple rounds of formulation, prototyping and evaluation, the final version of the design guidelines was formulated. The process is enacted in steps 7 to 9.
First, we hold several meetings, conversations and interviews during 2015 with different experts in order to deeply understand sociomateriality in the heritage domain (see Section 3.4) and in the heritage work (see Section 3.5). During those meetings, we discussed many times about the philosophical basis of the heritage domain, as well as recent transitions towards a territorial approach that grasp fundamentals of sociomateriality as that transitions have had an effect in the heritage work. This, together with the exploration of literature about sociomateriality at philosophical and empirical levels, determined largely how we should perform further activities to explore conversations in the RedPHI work. In this sense, the interest of explorations was based not only on how heritage experts get coordinated for sharing knowledge between projects, but also on how the sociomaterial particularities of the unit of analysis permeates the coordination of knowledge. Specific insights in this activity are presented in Chapter 3.

Second, the network of RedPHI actors was identified by interviewing some experts and exploring technical and administrative documentation provided for them. Participants from different universities, faculties, agencies, research centers and teams, public institutions, and other actors, where identified as well as their distinct roles as performing research projects, academic activities, consultancy services, among others. Appendix A, show the network map in the heritage domain for one of the RedPHI member. This activity was important in order to know boundaries of the heritage work and determine the scope of the exploration in terms of coordination activities. Given the size of the network, we decided to filter heritage actors, focusing only on experts.

Third, we ask heritage experts to answer a survey about interactions between them when performing the main heritage activities types such as research, teaching, consultancy and managing. Experts were asked to respond some questions about frequency, intensity, means and way of the interaction between them as well as the type and value of the information shared. Appendix B shows a sample of an interaction matrix between heritage actors performing research projects at RedPHI. By performing social network analysis, we investigate social structures in heritage activities through the use of networks and graph theory. A set of indicators of centrality, betweenness and closeness were calculated for each type of heritage activity. Results showed that the network of interactions can be considered as Scale-free (De Nooy, Mrvar, & Batagelj, 2018) and so a reduced group of experts are highly connected whereas majority of them have slightly connections. This is consistent with the observed in the field-work in which there are some heritage experts that participate in three or four of the heritage activities types. As it was quite difficult for the author of these dissertation to reach the whole group of experts, we conducted the next steps with those experts highly connected.

Fourth, by exploring information collected, having an additional set of interviews with heritage experts and reviewing coordination theories, several dependencies between knowledge coordination activities were identified and analyzed as well as the coordination mechanisms used by experts to manage them. Dependencies were directly related with the domain problem (see Chapter 3) but we also find a theoretical foundation in literature. Dependencies in the heritage work were related with work formalization, task assessment, heterogeneity, centralization, organizational structure, among others (Nova & Gonzalez, 2016a). Managing each dependency implies to explore at least one conversation between two different sociomaterial ecosystems. As trading zones are conversation spaces, then we can understand the sociomaterial imbrications
that produce and sustain coordination as a conversation among the heritage experts active in each project, and between dependencies and coordination mechanisms embedded in knowledge sharing practices.

Each dependency can be managed by one or various mechanisms, but we identified that experts chose them according to a preferential order, for instance, when a project involves experts from different institutions, they use instant messaging as first response mechanism, however, email or videoconference are second options to be invoked. This is a key point in the distinction of our realisms critical approach from the agential realism perspective because by using the metaphor of entanglement, we would overlook these conversations as we would be taken both agencies as given, ontologically and empirically. Grounding on the main argument of Leonardi & Rodriguez (2012), the empirical separateness and potential imbrication of experts, coordination mechanisms and dependencies can lead to designing technologies and organizations that work better.

Several coordination mechanisms were identified from literature and then complemented or modified by exploring the heritage domain. A huge portfolio of different coordination mechanisms is used by experts for managing each dependency according to perceptions of affordances such as collaboration, visualization, sharing, updating, centralization, among others; additionally, perception of constraints such as usability, storage capacity, interoperability, flexibility, access, among others, was also identified. An example of exploration of affordances and constraints is showed in Section 3.5, whereas Appendix C shows some affordances and constraints perceived during the heritage work. By exploring dependencies, mechanisms and affordances, a coordination matrix was built as an output of this matching process (see Appendix D). This step was important to deeply know the components of the sociomaterial ecosystems. However, as our interest was mainly in the conversations under which relationships between expert’s goals and mechanisms are negotiated, we also gathered arguments for using a specific mechanism in a particular contextual dimension. By focusing on these conversations, we were able to understand how heritage experts perceive affordances or constraints from coordination mechanisms (e.g. Google Drive) and meaning of the materiality of their actions. In a continuum of conversations, specific experts and coordination mechanisms became imbricated as determinate objects of practice (e.g. the diagnosis of the Pottery Factory). Thus, the imbrication metaphor offers ways to make analytical distinction which enable designers to relationally understand sociomateriality inside and between ecosystems across different temporal action–events.

**Fifth**, a critical realism view of sociomateriality leads to a temporal approach to provide a dynamic and historical understanding of coordination which are embedded in past, present and future. This step aims to shift the perspective of traditional procedures for exploring the “how” (mode) of coordination, toward a deeper understanding of the “what and when” (temporal practices) of coordination (Constantinides & Barrett, 2012; Faraj & Xiao, 2006; Venters et al., 2014). As Leonardi (2013) argue, without a consideration of time, no analyst could explain why practices arise, endure, or change, and this is one of the relevant differences from the Orlikowski’s work, in which temporality is ignored. By introducing time and by focusing on the process of the imbrication of agencies, we examined the temporal embeddedness of coordination processes, and
how heritage experts’ orientations to the future and past influence how coordination mechanisms become imbricated in emerging coordination practices.

Through interviews and surveys with heritage experts and following the methodological process posited by Leonardi (2013), we examined how people come to understand, interpret and deal with the materiality of technology-based mechanisms and how this existing materiality becomes imbricated with the knowledge sharing contexts into which it is introduced. We asked experts to answer questions regarding how people negotiate with materiality of technology during the heritage work; in which way materiality has supported or limited the knowledge sharing process over time; how experts change technology as they perceive constraints and how the change routines due to affordances perception; what role experts play in the creation of the sociomaterial over time; what are the particularities of the trading zones in which imbrications happen, among other questions. An example of this process is presented in Section 3.5.

**Sixth**, Joining the problem space from the case study with the solution space from literature allowed to abstract and formulate the design requirements. We aggregated theoretical positions and domain characteristic into design requirements and explain the goal of the KMS and why the sociomaterial design perspective can contribute to improve coordination in knowledge sharing activities. Design requirements are considered as input for the formulation of the reference architecture. We performed several iterations between rigor and relevance cycles in order to formulate the requirements, and then it was necessary to prioritize and refined them through literature research, discussions with heritage experts and practitioners and further evaluation. The final version of the design requirements is presented in Section 4.3.

At this point of the research, we wanted to invent entirely novel design guidelines for IT designers to develop sociomaterial KMS meeting the design requirements identified. To do so, we combined aspects of the relevance cycle and the conceptual framework supporting sociomaterial design in the rigor cycle. In general, we started from theory about sociomateriality with the goal of making it actionable through design guidelines. Then, we conducted two design workshops to understand how to do it. A workshop is considered as a structured meeting in which a selected group of stakeholders collaborates to define the workshop deliverables that represent preliminary ideas for sociomaterial design.

**Seventh**, two design workshops were conducted as a collaborative strategy to spark ideas about how to meet the four design requirements identified. The design workshops was carried out by using a cross-functional method, which involved different types of stakeholders from various areas of the business (Azadegan et al., 2013) and creativity (Maiden, Gizikis, & Robertson, 2004) which encourage innovative thinking and expression. During the workshops, concepts grounding further design guidelines were evolving through a scoping phase (*Concept ideation*), filtering phase (*Patterns and priorities*) and then a detailed formulation (Section 4.4). Each of these phases enacts sociomaterial conversations between heritage experts as well as among technology designers in different trading zones, which are represented by different workshop scenarios. A set of iterative and incremental steps (*planning, design, execution and evaluation*) were carried out when planning and conducting the workshops. Each step represents a conversation among theories, tools, procedures, performances and the use of those materials by researchers.
designing and facilitating the workshop. In this sense, several conversations took place when the goal of the workshops were specified; when ThinkLets (Azadegan et al., 2013) were selected; when each workshop was performed; and when final evaluation was reached. Complementary, a nested set of conversations were also enacted between steps as we followed an iterative approach.

**Planning.** The sociomaterial design is an evolving process that starts with the initial conversations in which the facilitator determines, adjusts and negotiates about the requirements and constraints with respect to the task, the stakeholders involved, the materials and resources available and the practitioner skills. These conditions together with the goal of the workshop determined the selection of the two ThinkLets developed during the workshops. The design workshop followed the principles of collaboration engineering (Azadegan et al., 2013) consisting of two ThinkLets:

- **Concept ideation:** we use cross-pollination of ideas by providing participants with a matrix whose columns enact design challenges related with meta-requirements and rows represent enabling solutions based on affordances abstracted from rigor and relevance cycles.
- **Patterns and priorities:** in this phase, participants filtered ideas using a quick-poll to reveal preferences and opinions and next, they identified strategic, high-value, luxurious and target items to be involved in the sociomaterial design of KMS.

Furthermore, the goal, strategy, procedures and expected results of the workshops were defined in this step. The workshop protocol was also designed in advanced including: introduction, activities, description, assignments, method, procedure, time and expected outcomes. The workshop attendees were selected by two main criteria, closeness with technology design and domain experience. Each group attended a different workshop but following the same design approach. And open invitation was sent to several people in both groups and later we received confirmation of people willing to participate. Nine heritage experts from RedPHI and six experts in design of technology for learning environments – a main component of the KS process (Collinson, 2004) – from Purdue University, participated in the first and second design workshop respectively. The design workshop at Purdue University is shown in Figure 4-1.

![Figure 4-1 Design workshop at Purdue University](image_url)
Several materials for the workshops were also determined and configured, for instance, presentation slides for the brief introduction in each workshop, cardboard, sticky notes, markers, tape, and so on. Configuration of materials responded to the workshops goal and method, as well as the room where they took place. These configurations are highly dependent on the ThinkLets selected, as each one required a particular and dispositional strategy in which materials were organized and place differently.

**Designing.** Once the workshop goal and requirements were sufficiently clear, the design approach was determined. The purpose of the workshops was to spark new ideas about how to design KMS from the sociomaterial approach. The workshop attempted to solve this question, as a general framework for the workshop: *How might we design an artefact (technology-enabled learning environments or KMS) that encourage knowledge sharing keeping in mind that both people and their several and heterogeneous materials are inseparable?* Then, four question were formulated as design hypothesis, each one representing each design requirement identified previously (Section 4.3). question formulated were: How might people (students or experts) coordinate the diversity of individual and educational materials during the learning processes? How might people (students or experts) connect their different ecosystems to one another forming collaboration and knowledge sharing spaces? How might we suggest the right tools in the right place at the right time to make people (students or experts) share their knowledge according to contextual changes? How might we provide people (students or experts) with options to effectively shape or craft their ecosystems to fit new requirements of knowledge? By using a critical realist lens (see Section 2.5), a set of affordances (improvisation, visualization, traceability and evidence, and flexibility) were proposed as a starting point to solve each question. Affordances were just suggested so that attendees had always freedom to make individual contributions from their own experience.

**Execution and evaluation.** The facilitator of the two design workshops was the author of this doctoral thesis who explained briefly the main concepts under consideration, such as coordination, knowledge sharing and basic concepts of sociomateriality and then guide the workshops. An initial configuration of the materials, time and place was performed according to the particularities of each ThinkLet selected. These orchestrations of materials and attendees defined trajectories of the sociomaterial enactment of the KMS design. The workshop materials never acted as an isolated actor in designing but were continuously imbricated and made significant in attendees as an aspect of the sociomaterial KMS construction for sharing knowledge. Integrated outcomes from the design workshops are presented in Figure 4-2. Left side shows ideas from technology designers and right side shows ideas from heritage experts for each challenge and scenario.
After finishing the workshops, a categorization process was performed in order to abstract a preliminary version of the design guidelines. Outcomes of the workshops function as semi-articulated hypotheses of potentially better forms for interaction (Zimmerman & Forlizzi, 2014). Following the workshops insights, the researchers selected and refined each idea into a more detailed hypothesis enacting each design guideline as shown in Figure 4-3. Ad hoc design, quotidian use of technology, meta-coordination, and visualization were identified as fundamentals for the design guidelines.
Those hypotheses emerged when the researcher performed several conversations with the information collected during the workshop such as photos, recordings, handwritten notes and utilized materials (filled out sticky notes, cardboards, etc.). The preliminary version of the design guidelines was formulated by configuring and reconfiguring the whole materials in a way that sociomaterial design was evident but solving the domain problem and extending current sociomaterial knowledge. In order to ensure completeness and consistency of the design hypotheses, researchers made several slightly different versions of a single guideline. Evaluation was carried out by verifying that the workshop was conducted according to the protocol established, comparing final outcomes with the expected ones, and by building a prototype of KMS by following the sociomaterial design guidelines.

Eight. A proof of concept (Nunamaker, Chen, & Purdin, 1990) of the KMS designed by using the design guidelines was utilized as an evaluation and tuning mechanism. Design requirements and design guidelines were used as input in this phase. Several conversations between available technologies (Section 5.4.4) and the researcher was held during the proof design but also between heritage experts and the prototype during the evaluation sessions as well as among technologies constituting the preliminary prototype. In this trading zones, several affordances and constrains were perceived by heritage experts and the author of this dissertation during the design and evaluation processes so that relationships between designers’ goals and technology’s features were broadly negotiated. As we posited in step fourth, by using the metaphor of entanglement, we would overlook these conversations as we would be focused on the design product, but not in the process itself in which negotiations happen.

Nine. In order to formulate the final version of the design guidelines presented in Section 4.4, we joined theoretical understandings with insights gathered from the design workshops and the proof of concept results. Our final set of design guidelines is the result from our conceptual and theoretical-practical development as well as several rounds of building and evaluating a prototypical implementation of a proof of concept to revise the design guidelines. Evaluation outcomes and final contributions from the SM literature led us to refine the design guidelines and to confirm the potential utility of our artefact for knowledge coordination enhancements in the heritage domain. Section 4.4 provides a detailed specification of the final set of sociomaterial design guidelines for KMS, and Chapter 5 presents detailed information about the functioning KMS prototype.

4.2 Architecture Scope
Design science research in Information Systems is about the creation and construction of useful (as a synonym of applicable) and generalizable IT artifacts to address important organizational problems. The IT artifact could be a technology-based solution (A. R. Hevner et al., 2004) aiming to lead important and relevant problems and opportunities in real domains. In our research the artifacts are the design architecture including architectural principles, implementation guidelines and a process structure and components. In this research, IT artifacts are conceived as interdependent and coequal with people, organizations, and social contexts in which they are used to support knowledge sharing needs (A. R. Hevner et al., 2004). From this perspective, designing
artifacts should be grounded in perceptions, conversations, negotiations and imbrications between people and technologies in different trading zones and so this design conception is also sociomaterial.

The result of DSR must be a viable artifact in the form of a construct, a model, a method, or an instantiation (S. March & Smith, 1995). While instantiations usually represent a solution to a singular design problem, constructs, models and methods can have different levels of generality and, as a consequence, represent a general solution to a class of design problems (Baskerville, Pries-Heje, & Venable, 2009). Winter (2011) argues that the two design goals of generality and utility are conflicting in constructing IT artifact. While increasing the generality, the individual utility of a solution for solving a specific design problem decreases, and vice versa.

Considering a balance between generality and utility, our design architecture is intended for collaborative and heterogeneous networked teams in the heritage domain. From the evaluation of our case study, the collaborative and heterogeneous networked projects showed that those teams have similar coordination characteristics and issues and their main routine is to share knowledge with colleagues, students and communities. The commonality in their way of coordination and knowledge sharing process demands and restricts the generality of the proposed design architecture. Applying the architecture to other kinds of groups requires different consideration on technical, organizational and epistemological factors, and this go beyond the purpose and capability of our research.

As domain experts might not be interested in higher generality because they are looking for benefits in their own context, as well as technology designers are waiting for new insights to improve designing activities in many settings, we opted for involving multiple and different project teams from the two contexts. Therefore, the design and evaluation cycle of this design architecture aims to balance the generality and utility of the architecture. Generality means the architecture can be applied in any context different to the one which originated the architecture, whereas utility intends for supporting domain experts in designing and using the KMS in their knowledge sharing activities. The use of the reference architecture will be presented and tested in the next chapter through a prototypical instantiation of the reference architecture.

The aim of this design architecture is to facilitate the design of technology-based coordination mechanisms for sharing knowledge in collaborative and heterogeneous teams. The implementation of the reference architecture is aimed at achieving high coordination levels via the design of knowledge management systems based on the sociomaterial perspective, at the same time it ensures the performance of those coordination levels by enabling knowledge sharing at different levels. In Chapter 5 we will discuss the implementation (KMS prototype).

A sociomaterial definition for reference architectures does not exist. In this dissertation, the notion of reference architecture has been adapted from (Taylor, Medvidovic, & Dashofy, 2009) and considered as a set of principal design decisions that are simultaneously applicable to multiple, distinct and interacting agencies, typically within an application domain, with different points of variation and a space in between for conversations and improvement. Our definition addresses the sociomaterial way of
thinking of this research (agencies features and their relations), defines the minimum architectural elements that should be considered in its design (agencies, imbrications, conversations and trading zones), states interaction between agencies (human and material), covers the different affordances than can be perceived when designing and using the KMS (points of variation), highlights the trading zones in which imbrications between agencies takes place (conversation spaces), avoids the deterministic relationship between agencies (conversation and improvement), and recognizes that materiality remains stable across time and space, while allowing space for improvement (disentangling, reconfiguring and joining together the agencies).

Other definitions cover only material aspects such as models, software elements and data flows (Angelov, Grefen, & Greefhorst, 2009), dismiss the role of the agencies by focusing primarily on best-practices architectures (Greefhorst & Proper, 2011), or on patterns and rules that must be followed when designing artefacts (Nakagawa, Antonino, & Becker, 2011).

As we posited above, we aimed to develop a generic reference architecture which implies applicability in multiple and different contexts, reflecting the requirements of the stakeholders in these contexts. In order to achieve this, we design the reference architecture at high level of abstraction (abstracting from the differences introduced by the heritage domain). However, the sociomaterial design process does not mean that the same affordances would be perceived by a different designer or that imbrications presented in Section 4.1 should be replicated, or that the prototype instantiation must be exactly the same as the one presented in Chapter 5. The reference architecture is prescriptive over the design process, including guidance for the design product, design process, and the design approach. However, designers can perceive other affordances and implement different design features on the KMS, so that the instantiation would be particular to a design context, domain needs, business goals, stakeholders, design materials, and so on.

Our reference architecture declares a structure of four guidelines that IS designers should follow if they want to design a KMS from a sociomaterial view. It also proposes affordances as variation points to instantiate the guidelines on the design of a KMS that overcome coordination issues in multidisciplinary and interorganizational knowledge sharing networks, but not restricted to this organizational setting. Therefore, our prescription is enacted by the design guidelines for KMS in general but we additionally propose specific affordances for designing a KMS in that domain, so that the reference architecture does not come with specific affordances that work in any context.

In this thesis, we use the concept of reference architecture to propose a set of design guidelines for an entire family of domain-specific KMS performing coordination for knowledge sharing activities. A concrete architecture for a domain-specific KMS can be derived by developing an artefact, which design process enact the sociomaterial approach defined in the reference architecture and by following a number of design guidelines composing it. Design guidelines include different elements of the KMS under development, such as structure, functions, interactions, properties, implementation, and others. A combination of design decisions enacting diverse material properties for the KMS can produce multiple knowledge sharing outcomes. In this sense, not all design decisions are architectural. In fact, the KMS performance will depend on both design decisions made in the process of designing KMS as well as people perceptions about whether material properties of the KMS afford or constrain their goals. Even though material
properties of a technology are common to each person who use a KMS, the affordances of that system are unique and variable according to particular ways in which an actor perceives materiality. Based on this, the design decisions are determined by context and are driving by sociomaterial considerations, as different perceptions of materiality from the KMS are possible. As each person use and interact with a different set of technologies to perform dairy tasks such as communication and knowledge sharing activities with project members, the design decisions include selection and combination of related systems which constitutes a personal artifact ecosystem. In this sense, design decisions also enact reshaping of the intended use of artifacts ecosystems to get a sense of ownership and to achieve their purposes as people perceive many possibilities for action. In addition, we defined the specific points of variation as any change that occurs in any contextual dimension presented in section 5.3.2. These points allow designers to provide alternative instantiations of the reference architecture. Variation points may appear from various contextual dimensions and at any level of abstraction. The relationships between variation points need to be explicitly captured and appropriately managed in order to fully understand the sociomaterial practices in the application domain.

Despite the fact the notion of design is central to reference architecture and to all of the concepts based on it, we are not aware of any reference architectures proposed for designing knowledge management systems following the sociomaterial approach. From the KM perspective, the nature of reference architectures enacts generalized knowledge of systems design. This perspective, positions the reference architecture in the area of knowledge management (Cloutier et al., 2010; Zimmermann, Miksovic, & Küster, 2012). The main goal of a reference architecture is to provide guidance for future architecture instantiations. Thus, capturing and sharing design knowledge such as architectural decisions is becoming a non-trivial process, but the main goal of KMS designing.

In our reference architecture, we capture how people enact human agency in response to technology’s material agency. The reference architecture captures people interests for using and modifying technology at hand within existing conditions and materials in order to coordinate knowledge sharing activities. This sociomaterial design considerations are beyond the boundary of the software components and operational processes. Although we have a broader scope, the system that we refer involves coordination of different technology-based coordination mechanisms, which are essentially software systems. It means that some knowledge from software architecture can be applicable on our reference architecture, e.g. integration and orchestration architecture. Our intention is to draw a reference framework that can be instantiated to the specific design of KMS embedding sociomaterial considerations. Although we focus on coordination for knowledge sharing processes in the heritage domain, the reference architecture we developed has a similar purpose in terms of providing solution within collaborative and heterogeneous networked projects in other domains. To frame the detailed design and development work in the problem/solution spaces, we derive the reference architecture from the design requirements and the knowledge base.
4.3 Design Requirements

Based on the abstraction from the RedPHI case study and the literature review we determine design requirements on our reference architecture for collaborative and heterogeneous teams to improve coordination in knowledge sharing activities. Requirement engineering has been studied extensively, e.g. (Dick, Hull, & Jackson, 2017; Sommerville, 2010; Sutclifff, 2012), but this dissertation is not focused on eliciting system or software requirements; instead, our focus is on design requirements. The design orientation lead research towards generating insights about how to improve organizational processes instead of only describe them (A. R. Hevner et al., 2004). The design requirements refer to aspects of an artifact’s functionality, structure and behavior, but also include analysis about usability, testability and verifiability features and constrains (Simon, 1973). In DSR, the design requirements are defined by what we discursively elicit as the problem space and create a technologically-based solution to the problem (Hovorka & Germonprez, 2011). Our understanding of design requirements is closely associated with the meta-requirements concept proposed by Walls et al. (1992) and general requirements described by Baskerville and Pries-Heje (2010).

For the purposes of the current dissertation, we use the term design requirement to refer to the set of features and functions an artifact must embody and what constraints it must satisfy in order to address goals, capabilities, purposes and limits of the system (Hansen, Berente, & Lyytinen, 2009). Specifically, we consider design requirements as the specification of particular materiality enacted by a KMS to accomplish a goal. They capture increasingly diverging and dynamic needs of experts during social interaction and evolution with the KMS. Consequently, design requirements state the material properties the KMS should have in order to solve coordination issues for sharing knowledge in collaborative and heterogeneous networked teams in the heritage domain. In this sense, design requirements must be obtained considering more diverse information sources in order to represent the entire domain (Nakagawa & Oliveira, 2007). In this dissertation, the design requirements are obtained from both theory and the case study and they will serve as an input for the design of the reference architecture.

In this dissertation, the design requirements are concerned with the improvement of the coordination process for sharing knowledge. Both design requirements constitute one of the central components of a design theory (Markus, Majchrzak, & Gasser, 2002). Design requirements are a special type of model (Prat, Comyn-Wattiau, & Akoka, 2014). Due to it is impossible to identify and characterize completely the dynamic and emergent aspects of coordination for knowledge sharing activities, our design requirements are characterized as ill-defined issues (A. Hevner & Chatterjee, 2010) and so the design of KMS tends to move outside boundaries of initial definition of the situation. Next, we present the four design requirements that make part of the reference architecture.

The first issue the exploratory case study revealed was independent and disconnected coordination ecosystems for knowledge sharing activities. Resources that are used for coordination process consist of personal ecologies (Jarrahi et al., 2017) that each domain expert configure and reconfigure in diverse ways. Artifact ecosystems means all the technology-based materials that people use to communicate, exchange information and share knowledge with others. Literature shows that making a coordination mechanism mandatory without considering
the influences of a partner’s ecosystems may be fatal (Cummings & Kiesler, 2008). The collaborative projects in the RedPHI show a huge and dissimilar set of interdependencies of different experts with various coordination technologies as they enact different coordination practices toward sharing knowledge with each other. The proper combination of this diversity can achieve higher level of coordination for sharing knowledge, but there is still a common problem caused by this diversity and it is a lack of interconnection among various technologies (Kallinikos et al., 2013). Therefore, the KMS must address individual coordination preferences but also it should allow connection of different ecosystems - no in the sense of interoperability- but as self-sufficient and independent modules within a wider coupled network of coordination relationships between artifacts. But connection is a context-awareness process in which people use, switch and combine different technologies according to contextual variables such as location, role, time, situation, interest and utilization. In this sense, the KMS must also ensure that different individual and group artifact ecosystems can be orchestrated to react to the contextual and situational opportunities and challenges of the collaborative work enabling coordination for sharing.

**Requirement 1 – Connection of ecosystems**

The KMS should embody mechanisms to naturally interconnect individual ecosystems in a high-level coordination layer enabling knowledge sharing between heterogeneous experts.

One of the most important tasks during the heritage project development is to share findings directly with colleagues, initially from the same discipline but in some milestones between different disciplines. The case study revealed that domain experts frequently switch between individual and group work and so there is a demand for a seamless transition between these two settings in various scenarios. For instance, architects share some findings about pathologic study with their colleagues and after getting feedback, they work individually from that point. As we showed in Chapter 3, heritage projects are based on loosely coupled workflow processes (Van der Aalst, 2000) which operate essentially independently, but have to synchronize at certain points to ensure task performance. Hence, the KMS must support various combinations of individual work and group interaction. For this, domain experts, especially working on research projects claim for a way to identify easily the course of the analysis that lead to findings. However, not only sharing knowledge about the finding by itself is relevant but also the method, resources, knowledge, people and capabilities which lead to this finding are necessary for a meaningful sharing of knowledge. In addition, domain experts asked for methods to directly share different knowledge with different colleagues according to the task they are developing. For instance, data about electrical network in an ancient church could be relevant only for electrical engineering team but no for the anthropology team, but papers presentations in workshops are important for the whole project team. Thus, combination of workflows preferably should be on different abstraction levels allowing both individual work and communication with other experts. This can be translated into the following requirement.

**Requirement 2 – Transition between workflows**

The KMS should support the transition and combination between individual and collaborative workflows enabling coordination in knowledge sharing processes.
Both the literature study (Leonardi, 2011; Nova & Gonzalez, 2016b; Zorina & Avison, 2011) and the RedPHI case study revealed that people change routines and technologies as they perceive affordances or constraints of materials. The two changes are episodic interactions that depend on technology characteristics such as flexibility and improvisation, which in turn are embedded in the work context where people can have it modified to fit their needs in relatively short order. These modifications are unpredictable and so the KMS should decline attempts at prediction but it must support those changes. In contrast, the KMS should recognize that coordination is emergent due to technology affords people different coordination possibilities depending upon expert’s perceptions. Thus, the KMS should support new and improvised ways of working and organizing, knowing that certain uses are enabled or hindered by the qualities afforded by the current technological artifacts. Knowledge sharing practices in the heritage domain has become different due to technological affordances of communication tools and so effectiveness in making decisions in fieldwork has increased. However, technological rules in some projects limit experts to take advantage from this potential so that routines have to be switched back in order to accomplish a contract regulation. Therefore, the KMS should support stable or ongoing processes of sharing knowledge allowing reconfiguration of coordination practices. This can be translated into the following requirement.

**Requirement 3 – Changes in routines**

*The KMS should support changes in routines and technologies allowing to configure and reconfigure functions and content according to particular project requirements.*

Coordination for sharing knowledge not only implies the connection of heterogeneous ecosystems but also the visualization of who and what is connected and the content of connected tools. As Leonardi & Treem (2012) argue, a KMS afford experts the opportunity to see what information others have contributed to a system. The literature study (Cross & Borgatti, 2004; Eppler & Burkhard, 2007; Wang & Mu, 2009) and the RedPHI case study revealed that one important and useful means to share knowledge is knowledge visualization. Architects are experts in sharing knowledge between specialists from different disciplines (engineers, lawyers, communities, etc.). However, one of the major problems in RedPHI is communication and understanding between heterogeneous experts with different backgrounds. Thus, the KMS should support the knowledge sharing process by making ontological and epistemological differences visible and communicable and by providing visual frameworks that help to bridge it. But, visualization process is also a search process (M. Chen et al., 2009). Therefore, the KMS should also help to reuse findings and experiences from prior projects in order to avoid reinvent the wheel, as the domain experts continuously claim. Visualization can be used as an effective strategy against cognitive overload but also as a way to discover knowledge storage in different sources inside or outside personal ecosystems. This can be translated into the following requirement.

**Requirement 4 – Visualization**

*The KMS needs to support the visualization and discovery of knowledge embodied in different ecosystems using consistent and meaningful methods for filtering in order to avoid cognitive and information overload.*
4.4 Design guidelines for sociomaterial design of KMS

The primary contribution of design science to knowledge is reflected in design principles as knowledge that guide designers during their design of a certain class of artifacts (Hevner and Chatterjee 2010). In this dissertation, we take the notion of design guideline as knowledge about creating other instances of artifacts that belong to the same class (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). This knowledge enacts a frame of reference that facilitates creation, manipulation and modification of artifactual forms (Purao, 2002). The frame of reference can contain constructs, models, and methods about the design process as an output of design research. The design knowledge aims to prescribe a desired approach to addressing a class of design situations. Based on these precepts, a design guideline specifies ways of building KMS in a reproducible manner. This knowledge about designing KMS can be useful to both, the next cycle of research as well as for design practices. In addition, the design guidelines represent the trading zone in which the problem space is connected with the design space through a set of engineering steps to provide a solution for them. This connection reflects prescriptive knowledge that can be used in the practice of building KMS. Thus, the design guidelines constitute a knowledge base for action (Baskerville & Pries-Heje, 2010; A. Hevner & Chatterjee, 2010) and they integrate procedural knowledge into design paths intended to produce more effective information systems (Walls et al., 1992).

Communication of essential design knowledge, abstraction and thus generalization of prescriptive knowledge, and progress in the process of developing more effective coordination mechanisms for sharing knowledge are some important characteristics of the design guidelines in our study. Design guidelines are closely related to the meta-design described by Walls et al. (1992) and general components depicted by Baskerville and Pries-Heje (2010). Consequently, we regard design principles as an artifact’s generic capabilities corresponding to the proposed design through which it addresses its requirements. For the purposes of the current dissertation, the design guidelines capture the knowledge gained about the process of building artifacts (technology-based coordination mechanisms) for sharing knowledge in the heritage domain following the sociomaterial approach, and encompass knowledge about creating other instances of KMS that responds to the same class of coordination issues. However, the design guidelines are also supported and inspired in the heritage work that experts perform during the project development. In section 3.4 we present a summary of how heritage experts carry out a sociomaterial process in order to design a SPMP which is unique, is elaborated by exploring conversations in trading zones between heritage objects and rural communities, and allowing access to the corpus of knowledge about the object and the process to protect it. In summary, the process to formulate the design guidelines is based on knowledge about the problem and solution spaces which involve: knowledge about exploration process of heritage objects; theoretical and empirical knowledge for designing technological artifacts from sociomaterial tenets; literature regarding how the heritage and design processes can be understood ontologically and epistemologically; and similarities between the two domains.

The design guidelines intend to support KMS designers in making necessary design decisions about methodological and operational tasks when they are looking for accomplishment of the design requirements in developing knowledge sharing artifacts. Even though the design guidelines are not infallible, the main concern is to select and apply the most appropriate
knowledge for specific design and development tasks. Design guidelines intend to encourage designers to make design decisions based on the sociomaterial approach when they conceive and develop a KMS using the reference architecture. We formulate a set of design guidelines considering relationships between both material agency and human agency (Chandra, Seidel, & Gregor, 2015; Seidel, Kruse, Székely, Gau, & Stieger, 2017) in order to avoid inconsistency (action or material oriented but not the two simultaneously) and imprecision (seen incomplete or misleading).

Each design guideline contains a set of affordances and design features as implementation guidelines. Compared with the design guidelines, which focus on the design decisions of the reference architecture itself, implementation guidelines provide instruction for designers in practice. They provide an operational and tangible landing of the design guidelines but they enact mainly suggestions that IT designers can adopt, adjust or reject in their own. Additionally, each guideline is formulated and supported through explanation of relevant contextual dimensions, enacting boundary conditions in knowledge sharing networks. Formulation process include a sufficient abstraction level in order to allow new instantiations in other contexts but generalizability only applies to those contexts which share the boundary conditions defined by the design guideline.

Each affordance is rendered in a set of design features. In case of design guidelines 1, 2 and 4, the design features are the functionalities effectively implemented in a KMS artefact to enable coordination for sharing knowledge. In case of design guidelines 3, design features enact some activities that designers could follow in the sociomaterial elicitation process of design requirements. They constitute the actual manifestation of the design guidelines and can be evaluated as part of an expository instantiation of the IS artefact. The list of design features identified to materialize each affordance are the ones that present the greatest differentiator of the KMS with respect to IS that reside outside of the purpose and scope covered by this dissertation.

4.4.1 Design guideline 1: Ad hoc design

*Designing for dynamic configuration and reconfiguration of the system’s material properties as the knowledge sharing context changes.*

According to Steve Jobs “design is the fundamental soul of a human-made creation that ends up expressing itself in successive outer layers of the product or service” (Stewart, 2011). In this sense, there is a traditional perspective about distinction between object user and object designer as conceptually and physically separate. From the sociomaterial perspective, people are considered as designers in their own right during the ongoing creation and reconfiguration of information systems. Often they behave as embodied designers acting as reflective and active participants in an ongoing design process and in the ongoing trajectory of systems (Germonprez, Hovorka, & Gal, 2011). For instance, people often add to or modify the technological properties on hand, thus, actively shaping or crafting the artifact in an improvised way to fit their particular requirements or interests (Orlikowski, 2000). In this sense, prediction strategies must be forgotten because the process of design does not end when a system is implemented and used. Therefore, fitting changing tasks, accommodating different artifacts, and reconfiguring functions and content according to contextual changes can enable natural coordination for sharing knowledge. In doing
so, it is necessary to incorporate in the KMS multiple levels of design from configuration of digital materials to managing information through interaction. Ultimately, the ad hoc design guideline intends to support changing work routines and technology, as people perceive affordances or constrains from work practices and materiality. In doing so, the KMS must be inherently flexible in order to support the change of existing work and knowledge sharing practices into ideal desired ones, even though these ideals are inconsistent between projects.

The ad hoc design guideline is based on the idea that a KMS must be fitted to particular specifications of contextual dimensions, affordance perceptions and imbrications that happen in a coordination environment. This is in line with section 3.4 in which we posited that SPMPs are ad hoc artefacts that must account for singularity in imbrication of material agency (heritage object) and social agency (inhabitants) as well as of their current and historical imbrications (territory). This similarity between both domains highlights the need for an ad hoc process for design KMS. In the context of sociomaterial design of KMS, the ad hoc design is guided by an ongoing process of shaping or reshaping the materiality of the KMS to align design with the coordination practices in the real world. Both domains (heritage and IT design) have an implicit consideration of time, because it affords experts the possibility to explain how imbrications arise, endure, or change. The pacing of imbrications in the heritage domain seems longer than in the IT design domain, this is due to materiality of heritage objects keeps generally stable across time whereas material properties of IT artefacts can be modified easily. It means that each domain involves a particular contextual time scale in which imbrications emerge. The view of sociomaterial design captures the way that people (heritages experts or IT designers) accomplish several contextual actions through a series of ad hoc explorations and interventions to build a design artifact (SPMP or KMS) that allow to reach a project goal (protection or sharing knowledge).

Design rarely starts from an empty state. Imbrications history influences, to an important degree, where and how new technological configuration can be done and prior decisions affect how those imbrications shape people perceptions of affordances and constraints. Configuration starts from considering the set of coordination mechanisms that heritage experts already use in everyday activities to share knowledge; this is an initial design-prior-to-use. Configuration supports the natural use of the technology affording functionality such as user searching, communicating and organizing. Reconfiguration occurs when experts perceive a mismatch between the KMS material properties and his or her intentions (human agency); this is a design-in-use. Reconfiguration allows the experts to tailor technology as a system that can be manipulated to serve changing contexts.

The ad hoc design allows experts to move from observation and use to experimentation and exploration of the material properties of the system forcing new imbrication process. This movement depends on possibilities to redesign KMS functions and content as heritage experts experienced different contextual dimensions in knowledge sharing networks. Therefore, a plethora of contextual configurations are possible each one enacting particular knowledge requirements to accomplish different project tasks. Thus, the KMS should afford more than just changing a background color or adding or moving content on a page, because heterogeneity increase coordination complexity for sharing knowledge.
• **Implementation guidelines for ad hoc design**
In order to lead with heterogeneity and complexity in coordination practices *editability, modularity, improvisation, tracking and persistence* are core affordances in designing KMS. The Table 4-1 defines the principles and their relationship to affordances and how the principles are evidenced in the KMS.

<table>
<thead>
<tr>
<th>Affordance</th>
<th>Design features</th>
<th>The design process entails...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editability</td>
<td>Project setting</td>
<td>Configuration and reconfiguration of functions and content</td>
</tr>
<tr>
<td>Modularity</td>
<td>Gateway setting</td>
<td>Connecting and navigating through heterogeneous resources and technologies</td>
</tr>
<tr>
<td>Improvisation</td>
<td>Emergent behavior</td>
<td>Emerging practices for sharing knowledge</td>
</tr>
<tr>
<td>Tracking</td>
<td>Comprehensive design</td>
<td>Comprehensive overview of resources, settings and practices for sharing knowledge</td>
</tr>
<tr>
<td>Persistence</td>
<td>In-situ representation</td>
<td>Sharing knowledge in asynchronous timing and location</td>
</tr>
</tbody>
</table>

Table 4-1 Guidelines for ad hoc design activities in KMS

Editability means the ability of an individual to craft or recraft content in the KMS, as well as the elements of which the artefact is composed (Kallinikos et al., 2013). The *project setting* principle specify how the KMS could be configured and what projects could be performed. A heritage project can be executed as a consultancy, research or professional service project. In all of them, heritage activities are performed in different locations, by different people, at different time, with different purposes and using diverse materials and so many design possibilities can emerge to manage the project information. In addition, even though each heritage object is unique, the way how experts manage information across different projects can have some similarities but also some noticeable inconsistencies, so that each project has a particular identity. Therefore, the KMS should support experts in designing an individualized fitting in organization and structure for specific project requirements and characteristics. This fitting involves flexibility in the ad hoc configuration of the project organization in logical sections through components, folders, project or component links, etc.; project setting at any time by all experts of the project team; adding or removing team members; connecting or disconnecting portions of the project stored in personal artifact ecosystems; exchanging information with team members and/or external experts and non-experts; supporting in-situ knowledge sharing; and controlling access to sensitive or public information.

In order to achieve modularity, intentional connectivity either through automatization (Jarrahi et al., 2017) or interoperability (Ktistakis, Akoumianakis, & Bessis, 2015) can enact a robust, stable and variable creation of group ecosystems for sharing knowledge. The *gateway setting* principle support the natural way how heritage experts manage personal information during a project. In particular, managing information across different personal ecosystems is challenging because heritage experts show strong preferences about where to storage information and how to share it with others, and even having a centralized system, information is still fragmented across different
devices and services and mostly in dyadic relationships which affect outcomes of collaboration. In this sense, designers should allow heritage experts to keep a seamless workflow allowing to connect personal services directly to the KMS instead of forcing them to use a unique technology. In doing so, it should be possible to structure a project through connecting different tools in a centralized environment enabling them a natural use of technology. As each expert owns a different set of services and sometimes all team members use a common service to manage information, the organization, structure and content of each service can be different within and between projects, and so the KMS should address this heterogeneous way of managing information. In doing so, the KMS can include gateway technologies (Jarrahi et al., 2017) such as support for add-ons in order to create connections and to reach compatibility between personal artifacts and the KMS structure, making feasible to utilize external artifacts as a KMS extension in an integrated system of knowledge sharing. A navigation pane of project settings, services connected and services content can enable access and overview of the project information allowing to cross through individual services exploring different resources. In addition, a search toolbox is also recommended to easily find information and to discover knowledge from the heritage project ecosystem. Additionally, it should provide support for hyperlinking other resources from both inside of KMS (projects and components) and outside of KMS (i.e. institutional repositories, government web pages, library resources, databases, etc.).

Improvisation reflects a changing set of competences and resources, which are recombined in continuously emergent fashions (Ciborra, 1999, 2004). The emergent behavior principle support participation, serendipity (Scott & Orlikowski, 2008) and emergent practices (Germonprez et al., 2011) in the KMS use and this is a main characteristic of a system designed using the ad hoc design approach. The KMS should support emergent design as heritage experts organize projects with total autonomy according to contextual changes. But it is clear that the design is limited by material properties of the KMS components. Emergency is related with tailoring the project content and setting based on previous configurations or just fitting changes in contextual dimensions. Emergent behavior can be supported through freedom and autonomy in designing the project setting but also annotating resources with personal ‘tags’ freely chosen from an unbounded and uncontrolled vocabulary. Social tagging can allow heritage experts to categorize, order, reuse and share information more efficiently than using classification schemes but also it enable make visible the experts work behavior afforded by the use of the technology (Treem & Leonardi, 2012). Therefore, the KMS should allow to tag knowledge resources such as projects, components and content enabling to discover common but hidden connections between resources and experts that can promote further collaboration for sharing knowledge. But tags are more than a keyword, they also enact a knowledge sharing moment because a different expert can use the tag to discover useful knowledge. In this sense, it would be useful to catch the whole details about tags such as who assign the tag and where, when the resource was tagged.

Tracking means following the context, meaning, function, or evaluation of imbrications as experts transits through their daily information lifeword (Hovorka & Germonprez, 2011). The comprehensive design principle provides a holistic and complete view of the project activity done by all experts of the project team, at all project sites, across all personal and groups ecosystems used by the team. Ad hoc design is a space where emergent and distributed behaviors are mixed. The KMS enable managing relevant content organized in non-defined project
structures and supported by heterogeneous technologies according to diverse contexts and so design is rarely a linear process. Therefore, a sociomaterial KMS design allow heritage experts to get a whole panorama of the current projects, keeping track of all the different resources that are important to their work. Traceability of both prior imbrications between KMS functions and expert interests and content changes can be done through a changelog with recent activity in the KMS and versioning services for tracking document changes. Using tools such as wikis and comments pane possibility to update and read someone’s or something’s status through other artifact, which is helpful to maintain a social awareness about the heritage project activities. Therefore, providing not only access to novel knowledge but also the ability to comment, discuss, give feedback, make questions, and other communication ways can promote sharing of up-to-date knowledge.

Persistency means knowledge that is accessible in the same form and place as the original display after the expert has finished his or her fieldwork (Treem & Leonardi, 2012). The **in-situ representation** principle specifies how the knowledge sharing process takes place in different contexts, in which experts and project teams carry out different project activities. In heritage projects not the all project activities are performed by all team members in synchronized timing and location, so that is especially important to share knowledge from different locations (heritage object site, project team office, classroom, government offices, etc.) because most of the project tasks are performed through fieldwork at different geographical locations. In doing so, the KMS can leverage in-situ knowledge sharing practices through interoperability with mobile applications that allow heritage experts to catch and share knowledge, including contextual information. However, because knowledge about publicly owned heritage objects must be open to everyone, people should have access to part of the knowledge in the geographical site of the heritage object but also the KMS should facilitate project team experts, which are located in different sites, analyzing field information to carry on other project tasks. In this setting, the KMS act as a mediator between two people each one using different artifacts and located at different sites but intending to share knowledge with one another.

**4.4.2 Design guideline 2: Second-order design**

*As the KMS represent a second order system, the KMS design process itself should be too*

This design guideline means that building a KMS, as a second order system aiming to coordinate a diverse set of coordination mechanisms, requires a second order design process in order to make a congruent design. In this sense, the design process itself should represent a meta-coordination process that allows building a KMS using available technologies, in other words, the KMS itself is a meta-coordinated system that enable meta-coordination between personal ecosystems for sharing knowledge. Noticeably, the type of materiality of the KMS is relative and determined by the materiality of the design process through which it is produced (Akoumianakis et al., 2015). In this sense, the meta-coordination can be instantiated through different prototypes based on different design processes and perceived in relation to different materials.

As we named this design guideline as second-order design, it is necessary to specify and distinguish between first-order design and second-order design. The figure 4-4 shows the first and second order design model and their relations. Both modifying the KMS functions and
The second-order design can emerge at two KMS design scenarios such as prior-to-use design and design in use. In the design guideline 1, we formulated a specification of first-order design as heritage experts configure the project settings, project ecosystem, and knowledge representations to perform specific project and knowledge sharing practices. Thus, heritage experts are able to reconfigure them in order to fit knowledge needs and project requirements (Abou-Zeid, 2007). However, when they perceive some affordances or constraints from the material properties of the current project configuration in the KMS, heritage experts can reconfigure them in order to fit knowledge needs and project requirements. In this sense, the organizational and structural reconfiguration of the KMS functions, based on perceptions of affordances and constraints, enact the second-order design. However, the second-order design is not only enacted in the coordination space for sharing knowledge between heritage experts but also in performing technical tasks to explore heritage objects. As we show in Section 3.5, the organizational and structural reconfiguration of the KMS functions, based on perceptions of affordances and constraints, enact the second-order design. In this sense, the organizational and structural reconfiguration of the KMS functions, based on perceptions of affordances and constraints, enact the second-order design. However, the second-order design is not only enacted in the coordination space for sharing knowledge between heritage experts but also in performing technical tasks to explore heritage objects. As we show in Section 3.5, the organizational and structural reconfiguration of the KMS functions, based on perceptions of affordances and constraints, enact the second-order design.
work with expert’s perceptions performing work routines and coordination practices for sharing knowledge.

In the prior to use design, the KMS organization determine the relations between technologies which define the system as a composite unity of a particular class of KMS and determine their properties as a system for sharing knowledge. But the design process also includes a structural specification of the KMS instantiation in the heritage domain. In the **first-order**, designers specify and configure the existing digital artifacts that can constitute the KMS organization in order to afford heritage experts functionalities to support design in use at the first order. In this scenario, the **second-order** design is enacted when KMS designers perceive affordances and constraints from technology being used to assemblage the system. Thus, new imbrication processes happen in reconfiguring the KMS as the material properties of the existing components do not afford potential to deal properly with the diversity of knowledge sharing practices between in heritage projects. However, designer’s perceptions must also be connected with heritage expert’s perceptions. KMS designers must be aware of affordances and constrains being perceived by heritage experts in practice in order to produce an effective design. Hence, designers must engage (not just communication) with heritage experts and their ecosystems in order to design a tailorable set of material properties from which they are able to share knowledge. This is vital in KMS design activities from the sociomaterial approach because the design process must be contingent upon heritage experts becoming KMS co-designers and collaborative design activities being enacted.

- **Implementation guidelines for second-order design**
  When designing the KMS, the second-order design level is enacted through an orchestration layer. The orchestration layer allows to compose existing fine-grained technologies into a single higher order composite service (KMS). From this perspective, the KMS is a material outcome of the design process materialized as a digital assemblage of other artifacts (Kitistakis & Akoumianakis, 2014). Orchestration can be done through an appropriate granularity of services, promoting reuse and manageability of the core system components. Designers can choose from the plethora of available technologies to build the KMS, and such applications can provide different support for varying knowledge sharing needs in run-time, but the challenge is to choose the appropriate artifacts to compose the system and how to coordinate them while fitting design requirements and contextual changes occurring in today’s dynamic technological landscape such as obsolescence, updating and novelty. In this stage, designers have two options when designing the KMS. The first option is coordinating available technologies in order to build the KMS as a meta-coordinated artifact, in which case designers are challenged by technological fitting of accessible tools, interoperability constraints, and capabilities to face different tools that often are not designed for later structural coupling (Mingers, 1991) with connotations of coordination and co-evolution. The second option enacts a traditional systems development process in which the whole system is developed following the same design perspective even though its individual components could be designed independently, through different design procedures. In order to support second-order design, the Table 4-2 defines the design principles as core steps in KMS designing activities.
Table 4-2 Guidelines for second-order design activities in KMS

<table>
<thead>
<tr>
<th>Affordance</th>
<th>Design features</th>
<th>The design process entails...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granularity</td>
<td>Assembling process</td>
<td>Selecting the KMS building components from a technological ocean to fit domain requirements</td>
</tr>
<tr>
<td>Space for action</td>
<td>Configuration space</td>
<td>Providing a space to identify, connect and manage applications and services that make up the KMS</td>
</tr>
<tr>
<td>Openness</td>
<td>Design in advance</td>
<td>Making a script about possible interactions of the KMS and its components in a real setting.</td>
</tr>
<tr>
<td>Interoperability</td>
<td>Cooperative design</td>
<td>Supporting communication between components through interoperability interfaces</td>
</tr>
</tbody>
</table>

Granularity refers to the minute size and resilience of the technologies assembling the KMS (Kallinikos et al., 2013). The **assembling process** principle specify how KMS designers should select technologies to assemble the system. In this regard, considerations about what kind of artifacts should compose the KMS are important for designers. These considerations are closely linked to design requirements and details from the application domain and also depend on whether the KMS is a meta-artifact or a new system performed. Whatever the mix of technologies and the option to assemble or develop a KMS, it is worth noticing that the capability of organizing and handling the KMS building components rests entirely in what affordances and constraints designers perceive from the material properties of each technology individually and a partial or total merge of all of them in the real-time of their practice. Design routines can change as designers perceive that the technological artifacts offer them distinct material properties to perform a good design. As a result of new imbrications, the resulting artefact provides for new possibilities for action and exhibits a degree of flexibility as elaborated in the empirical setting of the RedPHI.

The space for action is the space where intentionally designers fit the KMS for better conditions for sharing knowledge as an important dimension of sociomaterial imbrications (Bratteteig & Verne, 2012). The **configuration space** principle provides a common place to manage and aggregate all building components that are part of the KMS. As we posited before, heritage project activities are different across spaces, times, organizations, projects, and other borders, and so the KMS must be able to withstand this heterogeneity and to work independently of a centralized infrastructure. In KMS designing processes, cloud-based services can enable combining components into composite services or complete composite applications such as KMS. As the KMS is based on a modular architecture, coupling between applications should expose the underlying functions as services they can leverage independently or as a whole composite. In this way, each service could work separately, executing on their provider services infrastructure, or could be connected with complementary or competing services through APIs or gateway tools. In addition, cloud-based KMS may include the reuse of artifacts from other systems or more coarse-grained services, which can to avoid reinventing the wheel each time designers build a KMS.

Openness means possibilities to combine two or more physical objects to accomplish a specific task (Kallinikos et al., 2013). The **design in advance** principle is focused on building a KMS that fit purposes of the project team members as they use the KMS in practice. Purposes are different
as contextual dimensions of a heritage project change very fast and so diverse scenarios for sharing knowledge are possible. Designers should identify a common and preliminary set of scenarios in which heritage experts could confront diverse material properties of the KMS at different levels such as individual service, group services, and the overall KMS service. Scenarios support the idea that the KMS should work based on a modular architecture having enough flexibility to face heterogeneous activities, actors, and purposes and so the KMS could be considered as a multipurpose system. Noticeably, flexibility leverage many imbrication processes as experts can change field and office work routines and switch technologies according to the project needs and contextual changes. Moreover, combination of the KMS building components does not entail a coordination patterns, rather, it might be as many combinations as contextual dimensions changes.

One of the main material properties for a KMS is convenience to access and to modify the KMS content based on cross-device or cross-application interoperability (Jarrahi et al., 2017). The cooperative design principle focusses on coupling distinct applications or services in a KMS properly architected to support knowledge sharing activities. Whatever the sequence of technologies being orchestrated, designers should notice that every sequence must be supported by communication between the KMS building components and so the KMS design process must enable interoperability among both compatible and incompatible systems. By doing so, the KMS architecture make technically feasible to imbricate two or more building components as compatible complements in an integrated system of knowledge sharing at first level. However, at a second level, affordances and constraints are perceived by designers not only from the material properties of the KMS as a unit and from its building components, but also from the material properties of the interoperability interfaces that permit transformation between specific data formats required by each application or service being orchestrated. Consequently, certain routines in interconnecting services can change as the communication layer afford people diverse possibilities to share files, text and links, from native applications to others that compose the KMS. Tactics for interoperability (i.e., mash-ups, open APIs, sharing widgets, add-ons, etc.) are key variables to be considered within the KMS design process because they enable imbrications that qualifies the KMS as a digital sociomaterial assemblage exercising agency through their performativity.

### 4.4.3 Design guideline 3: Sociomaterial design requirements

**Eliciting design requirements through sociomaterial lens for designing a KMS**

Designing and developing a KMS requires observation of what coordination mechanisms people use day-to-day and how do they enable knowledge sharing process in a more efficient or effective manner. In the design guideline 2, we posited that design conversations are the space where designers match the KMS material properties with expert’s expectancies. Those conversations, are more than just communication between designers and heritage experts in requirements elicitation activities, instead, conversation aims to understand how the experts draw on perceptions to shape their interaction with their own artifact ecosystem (Leonardi & Rodriguez-Lluesma, 2012). The KMS design process is a conversation about what to conserve, what to change and what to value in the system (Dubberly & Pangaro, 2015). This conversation involves a process of observing and understanding how heritage experts face a situation as having some limitations, reflecting on how and why they improve that situation using technology, and how they act to
improve it. This enact a higher level of a nested set of conversations which points to understand the evolution of imbrications between heritage experts and the artifacts they use to share knowledge. In doing so, KMS designers should explore conversations between knowledge sharing traditions, in the first place, but also between people, between people and technologies and among technologies themselves. From this perspective, the requirement engineering process changes when designing a KMS using the sociomaterial perspective. Based on the socio-technical approach, literature about requirement engineering distinguish between user requirements, system requirements and domain requirements (Sommerville, 2010). This separation treats technology, people and contexts as a unidirectional causal influence or as a mutual interaction. However, what remains unquestioned in this logic is the assumption that the technology and people are separate but interdependent entities shaping each other through ongoing interaction and so it is possible to determine KMS design requirements separately. Therefore, in order to get consistency in the KMS architectural design, the requirement engineering process should also be based on a relational ontology that dissolves analytical boundaries between users, systems and domains.

Eliciting design requirements for a KMS through a sociomaterial lens is consistent with the way heritage experts acquire knowledge from sociomaterial interactions between heritage objects and communities living around them (see Section 3.4). In this sense, the elicitation process point to a deeper understanding of conversations between residents’ communities or neighbors, between people and the heritage object and between heritage objects (e.g. Qhapaq Ñan case in section 3.4). In the heritage domain, knowing the temporality and history of imbrications is extremely important because it allows identifying the evolution of human identity and idiosyncrasy. The goal of heritage work is to know how communities have evolved around materiality of heritage objects but also, how those objects have been constructed and transformed in order to lead social, political, religious, and economical changes among other effects. A central point of the discussion between monument and territorial views of heritage (see Section 3.3) is how important the sociomaterial relations are to understand the object and its material properties and thus to formulate a SPMP. Ultimately, the sociomaterial elicitation must focus not only on how heritage experts get coordinated for sharing knowledge, but also on the nature of the knowledge itself.

- **Implementation guidelines for sociomaterial design requirements**

Designers should discover KMS requirements exploring the broader sociomaterial ecosystem embodying personal cognition in quotidian activities but also from the dynamic relationships between people and their ecosystems to share knowledge. In this regard, is important to know some factors related to technology usage such as tracking and frequency of use, reasons for using it, selection and rejection criteria, alternative and complementary ways to use it, among others. In doing so, a set of questions can guide designers in exploring and understanding activities about prior and current sociomaterial imbrications between experts and material properties of technology they use in knowledge sharing processes. In order to support design requirements elicitation from the sociomaterial approach, the Table 4-3 defines the design principles in KMS designing activities.
Table 4-3 Guidelines for eliciting design requirements in designing KMS

<table>
<thead>
<tr>
<th>Affordance</th>
<th>Design features</th>
<th>The design process entails...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traceability</td>
<td>Informative</td>
<td>Exploring traces of prior imbrications in sociomaterial ecosystems</td>
</tr>
<tr>
<td>Uncovering</td>
<td>Idiographic</td>
<td>Uncovering patterns of routines in knowledge sharing practices and reasons for repeatability</td>
</tr>
<tr>
<td>Recognizability</td>
<td>Ordering</td>
<td>Understanding contingences in dynamic knowledge sharing contexts</td>
</tr>
</tbody>
</table>

A major challenge for designers is to explore and understand histories, traces and context about how imbrications were enacted in later activities (Leonardi & Rodriguez-Lluesma, 2012). Informing the traces and history of both knowledge development and artifact uses can help designers to identify prior conversations that form the foundation of current imbrication processes. In doing so, designers can ask experts about what role did the technologies play during the last heritage projects; how technologies enabled or constrained the knowledge sharing process during the last project and how they are enabling or constraining the current project; how the technology usage for sharing knowledge has changed from the last project to the current one; to what extent knowledge sharing tools afforded or constrain the knowledge sharing practices between projects; among others. In addition, designers should ask people for preferences about a particular set of technologies for communicating, information exchanging and knowledge sharing, because, the more an artifact is used, the more is the probability of new imbrications with it. Having an indicator of the frequency of use of artifacts ecosystems, can help designers to identify the point in which the KMS become more attractive to use as central environment for sharing knowledge.

Additionally, it is also important to uncover particularities of sociomaterial routines through idiographic attempts to reconstruct and analyze them (Gaskin, Berente, Lyytinen, & Yoo, 2014). At this point, an idiographic assessment could reveal some insights about routine use and configuration of sociomaterial ecosystems to perform diverse knowledge sharing activities. It is likely that people answers are focused on changes in contextual dimensions, and so, it is important to get prior and deep knowledge about the most common contexts in which experts develop heritage activities. In this sense, questions should lead to identify when do people use one artifact and when do they switch to another; at what moment and why experts move between artifacts; and when do experts broaden their personal ecosystems and when do they make it narrow. Additionally, knowing about the selection and rejection criteria, designers can also determine the extent in which experts are willing to include a novel technology in their personal ecosystem, but most important, if they are able to use it in knowledge sharing practices. The skilled designer, would understand which imbrications present the best and most feasible opportunities for reformulation and re-configuration (Leonardi & Rodriguez-Lluesma, 2012). This factor is particularly important, because the KMS itself aims to facilitate connecting personal ecosystems but it is also an additional artifact making up those personal ecosystems. In this sense, designers can explore how experts configure the ecosystem that they are going to use for a specific knowledge sharing activity; which constraints they point out to include a novel technology; what kind of constraints they overlook from current artifacts and what affordances make people use...
that artifacts despite limitations; what sort of contextual dimensions are the most decisive when selecting or rejecting technologies; among others.

Finally, recognition means to understand how people combine artefacts shaping meaningful structures to perform contextual knowledge sharing activities in practice (Constantinides & Barrett, 2012). An ordering exploration can lead to identify how people coordinate their personal ecosystems to perform dynamic knowledge sharing activities in heritage projects. In this sense, it is important to identify how people complement preferred artifacts with others of their personal ecosystem in order to deal with particular challenges in knowledge sharing activities. In this regard, designers can ask experts for information about when they decide to use one or more than one artifact to perform a task; how they decide what set of technologies is appropriate for a particular task; in what circumstances do they change the initial set; how do they combine artifacts to address complexity in project tasks; among others. The challenge in these factors is to reveal ways of managing personal ecosystems under fieldwork conditions, taking in account that artifacts are distributed, constantly configured individually and frequently merged with others in second order reconfigurations.

Noticeably, the factors presented before are not focused on eliciting functional and non-functional system requirements using the traditional methods, which are supported by aspects like system purpose, expected services, required characteristics, required hardware and software constraints, etc. Rather, the set of design principles aims to gather deeper insights and understandings about how people use materiality to become a coordinated knowledge sharing network. However, designers should obtain these insights in a longitudinal way, which means that a picture in a specific moment will probably not be enough to get a comprehensive panorama of the sociomaterial practices in knowledge sharing activities (Gaskin et al., 2014). Therefore, the engineering requirements process should not be one of the early stages of the KMS design process, rather, it would be an ongoing designing activity drawing on expert’s perceptions and feeding designers perceptions.

### 4.4.4 Design guideline 4: Metaknowledge

**Knowing about knowledge for enabling knowledge sharing**

In designing systems for knowledge sharing activities between heritage projects, both designers and experts can expect that everyone be able to find information, make decisions and solve problems fast and easily. In fact, people share knowledge by relying on their own personal ecosystem and by searching in impersonal digital materials such as databases, cloud computing services, hard disk, pen drive, etc. But, when a project involves heterogeneous actors performing different task through distinct artifact ecosystems, people need to develop awareness of knowledge and expertise of other ecosystems (Cross & Borgatti, 2004) and to get help from technology in information seeking activities that not only includes human actors. Fundamentally, experts need to have metaknowledge of what knowledge they are going to share, otherwise, it would make knowledge sharing impossible (Andreasian & Andreasian, 2013). Metaknowledge refers to knowledge about who knows what and who knows whom within the organization (Leonardi, 2014, 2015; Treem & Leonardi, 2012). However, from the sociomaterial perspective, metaknowledge goes beyond having yellow pages or a directory of organizational resources. In order to experts can share or acquire knowledge using the KMS, they must know what kind of
knowledge is available in the system, who is sharing that knowledge and with whom, and specially the context of the sharing process. Therefore, the KMS should show not only what resources are available in the system but also how experts are using them to perform project tasks and to make decisions. This can allow experts to discern with much greater precision the knowledge sharing features in the application domain.

As we posited in Section 3.4, knowing the history of imbrications between people (inhabitants or neighbors) and materials (heritage objects) is the most important goal of the heritage work. Specific details about prior imbrications and their evolution are the main resource to formulate a SPMP. The in-depth knowledge of the imbrications depends on several aspects such as the diversity of disciplinary views over the object, the scope of those views and the heritage project, but mainly rests on the access to available information regarding the heritage object as we argue in section 3.8. Through metaknowledge, some characteristics, similarities and differences between heritage projects can be easily identifiable and shareable, the KMS should make visible the project information jointly with the material context that determines relationships among human and material agencies, in order to leverage the knowledge sharing performance. The relationship between the knowledge shared and the context in which it was shared affords a glimpse into the sociomaterial view. Although the knowledge shared is certainly meaningful and real, it would be wrong to focus just on the actual value of the knowledge itself, as this value is clearly relational, at least in two senses. First, it is relational in the sense that, absent the context, the knowledge loses its value; and, second, it is relational because the knowledge acquires its meaning only in the context of a heritage project in which knowledge and context exist and experts or non-experts are able to acquire and understand the knowledge shared in context. This is especially important because the heritage projects enact a loosely coupled workflow process in which expert people complete tasks largely in isolation, in other words, at different contextual dimensions. Accordingly, the KMS should help experts to identify and recognize what knowledge other experts share by recreating the scenario and conditions in which the knowledge emerged and was shared.

- **Implementation guidelines for metaknowledge**

In order to support metaknowledge, the Table 4-4 defines the design principles in KMS designing activities.

Knowledge visualization designates translating knowledge into visible displays that others can use as the basis for their attributions allowing the social construction of expertise (Leonardi & Treem, 2012). A **discoverable design** can facilitate thinking together in a collective wisdom through engaging experts in graphic interpretations and explorations. It should be possible to make visible the whole sociomaterial ecosystem, visualizing people, projects, resources, documents, etc., including the specifications of each agent as well as different detail levels of each connection among them. This is the base to configure new sociomaterial relationships as people can raise awareness about how experts are interacting with materials in real practices. In addition, beyond features and relations, designers should also make visible actions performed by the experts with materials in the KMS because some of those actions enact contingent explanations for the unknown audience. Designers should expect that the KMS, rather than a simple mediator to communicate people, it should provide contextual richness (Seidel, Recker, & Vom Brocke, 2013).
In doing so, by being able to read a chain of comments, monitoring and exploring previous document versions, observing contextual information about tagging, and having a recent activity log of actions and relations produced by others, the heritage experts can develop understandings about how a particular project issue was overcome.

Table 4-4 Guidelines for enabling metaknowledge in designing KMS

<table>
<thead>
<tr>
<th>Affordance</th>
<th>Design features</th>
<th>The design process entails...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>Discoverable design</td>
<td>Visualizing actions, relationships and context in knowledge sharing activities</td>
</tr>
<tr>
<td>Customization</td>
<td>Customizable views</td>
<td>Updating and adapting visual formats to personal backgrounds and interests</td>
</tr>
<tr>
<td>Filtering</td>
<td>Zooming in practices</td>
<td>Reducing complexity in seeking information</td>
</tr>
</tbody>
</table>

Successful visualizations need to be customized to the cognitive background of the people (Burkhard, 2004) so that they can find and reuse knowledge in the KMS. **Customizable views** means differentiate experts’ searching abilities and different backgrounds offering them graphic formats than can be quickly, individually and collectively changed as a joint improvement of ideas. Accordingly, visualization of updated content is important but also the method of visualization determine if people are willing to use the knowledge displayed and to create new one by connecting with other people or materials. Customized views allow experts to reconstruct the picture in which knowledge was shared.

Filtering information means to avoid information overload caused by the increasing quantity and the decreasing quality of information (Meyer, 2010). **Zooming in** practices provide different angles for observation and interpretation of information in the KMS. Filtering information is an important step to reach proper meta-knowledge because not all materials are equally important for everyone. The KMS should allow experts to get an overview of the whole content through visualized information, and then, by reducing information quantity by zooming in and filtering, it should also be possible to provide them knowledge accessible on demand. In doing so, granularity of information is critical for properly knowledge sharing process. Relevance is determined by KMS users and so both designers and heritage experts should define jointly a set of criteria and levels for filtering significant information to be exposed to the audience in the heritage domain in order to meet knowledge needs.

4.5 Mapping design guidelines to design requirements

In this section we provided four design guidelines to facilitate the development of the reference architecture. To summary the discussion of the current section, the Table 4-5 presents the explanation of how the design guidelines satisfy the design requirements and contributes to the improvement of certain problems of coordination for sharing knowledge. These guidelines are expected to cover all the aspects of designing KMS from a sociomaterial perspective. We expect that the design guidelines can impact the measurable aspects of knowledge sharing. The contribution to measurable aspects will be evaluated in Chapter 5.
Table 4-5 Design guidelines satisfying design requirements

<table>
<thead>
<tr>
<th>Design Guideline</th>
<th>Satisfied Requirement</th>
<th>Explanation</th>
<th>Expected improvement to coordination for KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ad hoc design</td>
<td>2, 3</td>
<td>This guideline provides the foundation for supporting changes in routines and technologies and fitting different collaborative workflows. Designing for dynamic configuration and reconfiguration of the system material properties assure flexibility in coordination for sharing knowledge</td>
<td>• Knowledge access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• People and expertise access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Controlled access</td>
</tr>
<tr>
<td>Second-order design</td>
<td>1</td>
<td>Second order design process enacts a guide for meta-coordination. Meta-coordination can be instantiated through discreional prototypes, matching material properties with design requirements and dealing with different contextual dimensions</td>
<td>• Centralization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Knowledge retrieval</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Flexibility</td>
</tr>
<tr>
<td>Sociomaterial design requirements</td>
<td>1, 2 and 3</td>
<td>Observing and exploring artifact ecosystems, workflows, and changes in routines and technologies results in a deeper understanding of sociomaterial practices. This provides the foundation for ensuring consistence and coherence in the sociomaterial design process.</td>
<td>• Knowledge access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• People and expertise access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Centralization and knowledge retrieval</td>
</tr>
<tr>
<td>Meta-knowledge</td>
<td>4</td>
<td>This guideline provides the foundation for visualizing sociomaterial practices. Once the system is operating, people, materials and their relationships are visible in the system and so knowledge is revealed. This allows to show not only connected resources but also people’s behavior regarding to them and decision making in traceable contexts.</td>
<td>• Knowledge visualization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Knowledge access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• People and expertise access</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Making decisions</td>
</tr>
</tbody>
</table>

4.6 Process structure and components
As introduced in the design guideline 1, the sociomaterial design process entails a dual design perspective that requires an initial design-prior-to-use and a secondary design-in-use. The activities comprising the architecture have different affordances and design features to support configuration and reconfiguration of material properties of technology being used to build and use the KMS at the initial and secondary design levels.

The design guidelines comprising the reference architecture offer different affordances, supporting flexibility and emergence at the design-prior-to-use and design-in-use levels. We consider that for a complete, consistent and coherent sociomaterial design process the four design guidelines should be jointly executed. In our reference architecture shown in Figure 4-5, we have two axes capturing the following four elements:

- **Design-prior-to-use:** concerns the whole activities developed by designers to design and build the KMS before use. It involves DG1, DG2 and DG3 as KMS designers must elicitate requirements before designing the KMS, identify affordances of available materials to build it as a meta-coordination artefact composed by expert’s ecosystems, choose design approaches and technologies, perform the space of design and configure the KMS to offer flexibility.

- **Design-in-use:** enacts the functionalities that domain experts can use to configure and reconfigure dynamically the KMS in practice. It involves DG1, DG2 and DG4 as experts can modify material properties and content of the KMS to fit project goals and identify
relevant knowledge in the system, both based on affordances and constraints perception of the system functionalities and information visualized through them.

- **Perception:** represents the observing process of current and planned design conditions as having some materialities affording or constraining actions. Perception occurs in DG2, DG3 and DG4 as designers observe the specific particularities of the application domain and identify pros and cons from technological components to build the KMS; and domain experts are aware of action possibilities the KMS afford or limit and are able to figure out what knowledge offer some level of usefulness for a project task.

- **Action:** denotes the practical design activities that designers and domain experts perform to design, build, configure and reconfigure the KMS. It involves DG1, DG3 and DG4 as designers develop conversations with the domain experts and their artefacts in order to determine how affordances should be implemented to afford ad hoc design in the KMS; and experts configure and reconfigure the system material properties in practice and discover knowledge from the network of connected ecosystems.

![Figure 4-5 Architectural view of our reference architecture for sociomaterial design of KMS](image)

In Figure 4-5, the layered surfaces denote clusters of the sociomaterial design process, which correspond to the elements we have described in Section 4.5. The labeled boxes denote each design guideline composing the sociomaterial design process of KMS. Proposed design guidelines are presented in a purely functional manner through implementation guidelines with affordances and design features. The labeled strings attached to each design guideline denote the action possibilities that the KMS should afford initially to designers for designing the system and to domain experts in order to configure and reconfigure the system in practice. The arrows denote relations between design guidelines. Relationships result in interactions between these guidelines depending on the design process stage. Each arrow enact flow of information necessary to
perform a specific activity of the sociomaterial design process. Finally, the design guidelines are located in the middle of each axis because these boundaries are fuzzy as there is no specific time, phase or moment in which designers or domain experts perceive affordances and then design. Likewise, there is a blurry line between design-prior-to-use and in-use design because the sociomaterial design is an ongoing process in which affordances lead to configure and reconfigure the system continuously in order to fit new purposes.

4.7 Expert review for the reference architecture

At this time, the reference architecture became a conceptual formulation from the knowledge base about the problem (Chapter 2) and the case study findings (Chapter 3). Before the reference architecture was instantiated in a KMS prototype as a validation strategy (Chapter 5), it was reviewed by experts to gather data about the possible usability and usefulness of the artifact. The architecture review enacts a way to increase the likelihood that a system architecture will be complete and consistent (Maranzano et al., 2005). The architecture review is designed and performed to answer “Will the computer system to be built from this architecture satisfy its business goals?” (Kazman & Bass, 2002). We performed an architecture review in order to assess the ability of our reference architecture to deliver a KMS prototype capable of supporting KMS designers in fitting the design requirements. In this section, we present our expert review process and result as primary evaluation of the reference architecture. Our review process covers the design requirements and the design guidelines including the implementation guidelines that were extensive tested through the prototypical implementations presented in Section 5.5.

4.7.1 Review method

According to a survey by Babar and Gorton (2009), the most common methods to review and verify an architecture are experience-based reasoning and prototyping. In the design cycle of our research framework, both the methods were employed to evaluate the reference architecture. We first use expert review to evaluate the design requirements and then Chapter 5 presents the prototype as an instantiation of the architecture. We conducted an expert review session to evaluate the design requirements. In addition, reviewers also evaluated the implementation guidelines through a proof of concept with a preliminary version of the KMS fitting the requirements. In order to perform the expert review, we follow the principles and process suggested by Maranzano et al. (2005): screening, preparation, review meeting and follow-up.

**Phase 1. Screening.** The primary version of the architecture has been developed and an architecture review is required.

**Phase 2. Preparation.** The project team selects a review team and works with the project to determine the number of reviews and the initial review’s date and agenda.

**Phase 3. Review meeting.** During the review meeting, the project team presents its problem statement and how the proposed architecture solves it. The reviewers ask questions and record issues they believe could make the project an incomplete or inadequate solution to the problem.

**Phase 4. Follow-up.** The review team delivers report/comments with the review’s findings to the project team. The project team and management must respond to resolve issues the review raised, if there is any remaining issue. This can be done by adding a particular review with a smaller group of reviewers.
In the next section, we will present the setting of our architecture review based on the guidelines posited by Maranzano (2005).

4.7.2 The review of the reference architecture

Phase 1. Screening.
The first step of the review process was to define the purpose of the review. Evaluation requires the definition of how to perform the evaluation and to how to gather and analyze data (A. R. Hevner et al., 2004). The expert review meetings were carried out on February of 2018.

Phase 2. Preparation.
First, the problem statement was defined and presented to the reviewers (see Figure 4-6) as an introduction for each review session.

Figure 4-6 Heritage experts verifying design requirements

Briefing experts prior to review was an important step to set relevance and thus increase experts’ attention and sincerity levels (Krueger, Page, Hubacek, Smith, & Hiscock, 2012). As part of the planned materials, we prepared a presentation designed to support the review goals, which included the design requirements and some conceptual ideas for the KMS prototype that could meet them. During the presentation, we explained some technical details of the architecture as well as affordances and constraints of the selected KMS components. Second, technical details, preliminary design decisions, the overview of the KMS, and other choices and specifications were explained during the expert review.

Third, a set of independent experts from RedPHI conducted the review. The team was selected on the basis of their expertise and their independence from this doctoral research. In order to ensure reliability of the review outcomes, the review team consisted of heritage experts different from those involved in the case study. The architecture review included nine heritage experts. All the expert team members have an extensive background in heritage projects as well as experience
in teaching, research and consultancy projects in the heritage domain. Due to personal schedule of the reviewers, they were invited to participate in groups of three experts, and so in the review we held three sessions. An import aspect to ensure reviewer’s willingness to participate in the evaluation was to highlight, before and after each session, the review’s value (Kazman & Bass, 2002). The content, method and the reviews approach were identical in each session in order to avoid bias in findings.

Four, each review team was invited openly to attend the session. We motivated reviewers to openly raise negative or critical opinions because they are very useful to identify elements of the artifact design that would not be usable or useful in specific contexts, and the reasons to adjust the artefact (Wieringa, 2014). The review team were able to verify the problem statement, ask questions, and identify possible problems with the design requirements and the implementation guidelines. Fifth, feedback to improve the architecture was the main focus of the review process. Most of the expert recommendations were turned into adjustments to the architecture.

Phase 3. Review meeting
The nine experts agreed in considering that the design requirements fitted the reality of coordination for knowledge sharing activities between heritage projects. Experts highlighted flexibility in configuring projects as the breakthrough for improving coordination. Four experts remarked that Requirements 1 and 3 are the core of coordination activities in multidisciplinary and interorganizational projects as the KMS can be adjusted to the project needs and not vice versa. They claimed that “the system seems flexible enough to perform sequentially or parallelly, a personal project or a big research project but also a consultancy project that sometimes involves different and novel methods and formats that do not fit the research project standards”. Distinguishing between fitting the system to the project needs and fitting the project needs to the system rules provide a huge opportunity to ease the appropriation of the KMS as a sociomaterial system. The first option meets the sociomaterial design whereas the second one is more related with sociotechnical design.

They also found that Requirement 2 is key when coordinating personal or group activities. Two experts claimed that “In a big project, we usually work individually or by disciplinary areas in our own tasks, but regularly, we have to meet with the whole group, specially to build partial reports, and so we have to switch our routine from individual to collaborative work. This is challenging because each team member manages their own knowledge in a different way but sometimes, they have to make it available to everyone in order to reach the project goals”. Supporting individual and group workflows but mainly allowing transition between them would enable further coordination and flexibility than just exchanging individual resources in a dyadic way. They expected that the system based on sociomateriality would allow a higher coordination level in knowledge sharing activities that the personal coordination mechanisms alone do. The expected outcome of this requirement is to balance the common understanding between different backgrounds with individual and groups productivity.

Concerning the requirement 4, all the reviewers accepted that visualization enables knowledge discovery and facilitates knowledge sharing within and between projects. One expert highlighted that “finding knowledge in a graphical way and having a possibility to filter it is a key
affordance to enable knowledge seeking and discovering without looking for indexed or annotated lists”. They strongly agreed with having visual access to information and contributions from other experts no matter what discipline, group or organization they belonged to. Moreover, they also remarked that visualizing too much information can be a bit confusing and so it is necessary to find a balance between how much information is visualized and the power of filters. They expected that the filter service would facilitate the work of the expert and non-expert users but also promote knowledge, people and institutions access in order to effectively share knowledge between heritage projects.

Internal experts accepted that the requirements enact the coordination issues for sharing knowledge in RedPHI. As each requirement was presented through contextual and real examples, reviewers also had the interest to look forward the KMS prototype to see its real potential for enabling knowledge sharing between heritage projects. The external experts also participated in the proof of concept to be aware of benefits or issues of the KMS concept built by using the design guidelines. The proof of concept is a way to demonstrate that the designed artifact is consistent with its intended purpose and solves one or more instances of the problem (Nunamaker et al., 1990). The preliminary KMS prototype design made them realize some important aspects that need to be considered. First, having flexibility to design the KMS in order to fit the project needs can mediate expert’s dynamic interactions with content and project settings and could determine if the system is properly understood and appropriated or whether it could be inhabited or misused. Second, even though they had considered the necessity of meta-coordination instead of making mandatory the use of just one system for everyone in a project, they found that coordination of personal artifact ecosystems has promising flexibility in knowledge sharing activities. However, they suggested that both connecting independent tools and connecting personal artifact ecosystems, implies interoperability to guarantee information exchange and knowledge sharing without additional complexity. Third, reviewers mentioned that when using the system, technical support is desirable to manage the technological tasks that are out of the scope and abilities of the heritage expert team. This role may be played by the team manager in case of a small project, but in a larger one, it could be necessary to involve an IT manager in the project team. The ultimate goal is to avoid the complexity of adding more processes to share knowledge than those related with specific requirements. Four, as mentioned by a RedPHI expert, the KMS affords knowledge sharing between heritage experts, however the knowledge discovery process is completely human. Our architecture did not provide technical support to include knowledge engineering principles and tools. We include this suggestion as future work.

**Phase 4. Follow-up.**

After the expert review meetings, two RedPHI experts continued with a follow-up review on the feasibility of the architecture but specially on technical details to keep in mind for the KMS prototype. The follow-up session was performed on March and April of 2018. As experts started to contemplate the design requirements in their quotidian work and they became aware of the affordances from the KMS components by using it on their own, they offered additional feedback. Reviewer’s comments focused on how to fit visualization as much as possible to the heritage context needs. They proposed some ideas about presentation of information as infographic views in KUMU. In addition, they claimed to present just a minimal part of the whole content in OSF in order to avoid cognitive overload in non-expert users. They also recommended to afford people
with a possibility to perform a deeper exploration of the content visualized in KUMU as they find some interesting topic. Finally, the feedback pointed out that is difficult to find a KMS that can include the connection of the personal artifact ecosystems keeping a seamless workflow, which is helpful to facilitate coordination. Most of the reviewer’s recommendations suggested during the expert review, the proof of concept and the follow-up session were included in the KMS prototype presented in chapter 5.

4.8 Implications of sociomateriality in the design process

The current research has three main discussion topics about the consequences of our design decisions argued in sections 1.5.1 and 2.5 in the heritage domain exploration, as well as in the identification of design requirements and formulation of design guidelines.

- Implications of the critical view of sociomateriality in the heritage work

Even though we did not aim to debate about what sociomaterial tradition would properly match the sociomaterial dynamic in the heritage domain, it is clear that the critical realist view affords a useful conceptual and empirical lens. Critical realism was helpful to explore and understand the dynamic of the heritage domain as a real problem. In terms of materiality, the heritage objects can be considered as causing events in the real world and their nature is based on the structure of their components. Heritage objects have a separate and individual existence from the moment of their creation, even if it is a natural or human creation. Additionally, the separation of social structures, agencies and natural phenomena provides an analytical power to understand the purpose of the heritage objects and their inhabitants. As each entity has inherent properties and intrinsic capabilities that are relationally imbricated across time and space, it is possible to examine conversations between agencies and to identify historical imbrications, which is the core of the heritage work. Describing how agencies come together and produce emergent imbrications through their interaction is a research stream for different disciplines around heritage such as history, anthropology, sociology among others. In this sense, tracking perceptions of affordances across time and space is an important step when exploring heritage objects from a sociomaterial view.

- Implications of the critical view of sociomateriality in the design process

By adopting the sociomaterial perspective of Leonardi’s work, which is grounded on the critical realist view, we were able to design, explain and execute the sociomaterial process to identify design requirements and formulate design guidelines. This view leaded us to explain the design process and the design product through holistic relationships between agencies. ‘Imbrication’ allowed us to understand and explain several aspects in this dissertation. Through the analytical dualism lens and the agential perspective, we reached a greater understanding of roles and uses of technology-based coordination mechanisms in supporting knowledge sharing processes within and across RedPHI and how those process shape technologies. This was powerful to determine how and why the separate coordination mechanisms and the knowledge needs become the “sociomaterial” and persist over time. Therefore, we were able to provide explanations for the social phenomena called coordination for sharing knowledge. The explanations are based on
temporal imbrications between experts and mechanisms and the ways in which contextual dimensions determine characteristics of these interactions.

Critical realism also allowed us to observe and explain the coordination practices for sharing knowledge with their natural particularities, in which heritage experts do not perceive the material and the social or the technological and the organizational as interpenetrated entities. When sharing knowledge at RedPHI (see Section 3.6), heritage experts can relatively easily point to a coordination mechanism such as Google Drive or a heritage policy book and say “this is material” but they would likely have a hard time fathoming that they are in any way social. That is not to say that heritage experts cannot reflect upon the social ways in which they get coordinated, actually two of the experts with whom we held several talks, meetings, interviews and coffees during long hours, ended up with such reflections. However, the empirical observation of the heritage work showed that they do not act in that line of thought; they just interact with materiality to meet knowledge needs without any consideration about intra-action and boundaries of the matter composing the coordination mechanisms.

However, one of the most valuable aspect of the critical view of sociomateriality is the concept of conversation which helped us to understand how imbrication occurs in coordination practices and how relationships between people, dependencies and mechanisms are negotiated in different trading zones according to dynamic contextual dimensions as point of variation. Conversations showed that people use, switch, toggle, substitute and combine multiple and different mechanisms according to contextual dimensions of the ongoing coordination practices and this insight was important to posit coordination as dynamic but mainly as sociomaterial and temporal. Conversations and the affordance perspective were also fundamental to understand sociomaterial ecosystems in practice because the ecosystem itself is a result of several imbrications between agencies and, thus, it is necessary to consider the social context and the materiality as separate but explaining to what extent and at which time they join together. The affordance perspective led us to explain how and why imbrications between coordination mechanisms and knowledge needs occurs in a dynamic, emergent and volatile way and why coordination practices come to take on the shape they do in the heritage domain.

Available tools to capture empirical data from RedPHI can be also problematic without the dualism between matter and subject. By keeping the analytical distinction between agencies at RedPHI and by being able to fall from one side to another – either focusing on coordination mechanisms as having materiality that is stable across relations, or emphasizing the agency of the coordination mechanisms at the determinant of understanding knowledge sharing in practice – we were able to discover heterogeneity of coordination mechanisms, visualize the network of heritage experts, investigate social structures in heritage activities, identify affordances explore conversations during imbrications, among other steps. Additionally, a critical realist approach affords options to describe how coordination actions are performed in practice, but mainly to explain why coordination emerge in the way it does.

The critical realist view of sociomateriality allowed us to express the design guidelines, using the notion of affordance. This makes sense because our design capabilities are in fact limited and always mediated by our perceptual and theoretical lenses as Mingers et al. (2013)
posited. Therefore, each guideline included a set of set of implementation guidelines composed by affordances and design features that aim at helping IS designers in design and implementation activities of KMS by deriving knowledge from our reference architecture. Because of analytical separation between material and human agencies, we were able to purpose a set of design features as material properties of the KMS that afford different possibilities for design based on the contextual dimensions in which they are used. Both design guidelines and implementation guidelines were formulated by several conversations with empirical data gathered from RedPHI, theoretical insights form literature about sociomaterial design and materiality of available technologies to build the KMS prototype (see Section 5.4.1). Negotiations between those agencies led us to formulate the preliminary and then the final version of the reference architecture.

At empirical level, the design guidelines were formulated and refined through design workshops in which we separated analytically the design scenarios (social setting) from enabling solutions (material properties of different technologies) as a strategy to generate wide-ranging ideas about sociomaterial design. The match between both entities is a proper example of imbrications emerging during the design process. As Leonardi and Rodriguez (2012) suggested, a skilled designer has to be able to identify both the best and most feasible opportunities for reformulation and re-figuration of the design product and the imbrications that can be redone in new design iterations. During the workshops, designers were responsible for putting the social and the material together so that different kinds of designers’ perceptions leaded to different inputs for the design process. Finally, we also analyzed affordances perceived for designers during the evaluation sessions for the KMS prototype and figured out that, as we identify when exploring coordination in practice (see Chapter 3), heritage experts will use the same KMS in many different ways.

4.9 Summary
In this chapter, we presented our reference architecture with its design requirements, design guidelines, implementation guidelines, process structure and components, and the expert review on them. In order to improve coordination for sharing knowledge, the proposed reference architecture enables the design of sociomaterial KMS, enacting the flexible and ad hoc design of coordination practices that meets heterogeneity and complexity in knowledge sharing activities.

Returning to the third research question, we formulate the reference architecture that guide IS designers at operational and empirical level when designing KMS. In this way, the research findings from the literature review on Chapter 2 and case study on Chapter 3 were used to construct the reference architecture. The sociomaterial design process of coordination artifacts is summarized as a reference architecture which orients the design of an entire family of domain-specific KMS improving coordination in knowledge sharing activities. The reference architecture includes four design guidelines that lead the design process at high level allowing generalizability, but also involve a set of implementation guidelines that could guide the design process at developing level. The design guidelines capture the knowledge gained about the process of building a KMS following the sociomaterial approach, and encompass prescriptive knowledge to design IS artifacts. Each implementation guideline provides instructions about what affordances and design features should be designed in a KMS in order to adopt our reference architecture. The
interactions between design and implementation guidelines that constitutes our sociomaterial
design process are exposed as process structure and components.

Expert review was employed as the evaluation of our reference architecture in a primary stage. Useful feedback was gathered to improve the reference architecture and also help the progress toward further evaluation. An empirical evaluation of the reference architecture is presented in Chapter 5, as a prototypical implementation of a KMS in the heritage domain.
5 A KMS PROTOTYPE FOR TESTING THE REFERENCE ARCHITECTURE

This chapter and chapter 4 report on the design cycle of our design science research framework. This cycle integrates the findings from the rigor cycle (Chapter 2) and relevance cycle (Chapter 3) to build the artifacts in our research. This chapter presents a KMS prototype designed from the reference architecture for testing whether the implementation of the reference architecture can improve coordination for sharing knowledge between heritage projects.

We start this chapter by presenting the prototyping approach, followed by a modeling methodology about how the sociomaterial design process is modeled. Thereafter, we discuss the design process followed to design the KMS consistently. Then, we present the selected components that compose the KMS and the, we expose the detailed process followed to build the prototype. This chapter is ended with the evaluation process by checking models, verifying the implementation guidelines and validating the KMS prototype.

5.1 Prototyping approach

According to Hevner (2004) “Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation”. Prototyping is used as a proof-of-concept to demonstrate feasibility (Nunamaker et al., 1990). As we mentioned in Section 1.4, in our research the artifact is a reference architecture composed by a set of four design guidelines, implementation guidelines with affordances and design features and a process structure and components. The implementation of the reference architecture is aimed at achieving high coordination levels via the design of sociomaterial KMS, at the same time it ensures the performance of those coordination levels by enabling knowledge sharing at different levels. In this Chapter we discuss the implementation of the prototype and Section 5.5 contains the evaluation.

According to the definition of reference architecture given in Section 4.1, the reference architecture consists of the on following elements:

- Design guidelines: the foundation for making possible the design of IT artifacts based on the sociomaterial approach;
- Implementation guidelines: how designers can instantiate design guidelines by designing affordances and implementing design features in the KMS, and;
- Process structure and components: the components of the design process and their relationship. The process structure and components are based on the design guidelines.

During the implementation of the KMS prototype, we considered factors involved directly with the application of the KMS. We developed the KMS prototype, building on the conceptual framework, the design requirements and the empirical research gathered from the application domain. As we posited in DG2, the KMS **represents a meta-coordinated artifact** in which several and diverse technologies can be connected and disconnected dynamically as people perceive new affordances from materials they use. However, the KMS itself enacts a higher order composite service built through existing fine-grained technologies and assembled as a single digital artifact. Thus, the KMS affords meta-coordination but also enacts a meta-coordinated
artifact. Consequently, we were challenged by technological fitting of accessible tools, interoperability constraints, and capabilities to face different tools that often are not designed for later structural coupling (Mingers, 1991) with connotations of coordination and co-evolution.

In this chapter we discuss the implementation of the KMS. In the first section we provide the modeling considerations in developing the system. We then present the process followed to design the prototype and we finally present considerations and details of the sociomaterial design process.

5.2 Modelling technologies for sociomaterial design
In this dissertation, the way of modeling involves a set of models that enacts the sociomaterial design process of a KMS. Modelling is the manner how KMS designers construct conceptual and design representations detailing the way to design, implement and test the system at a designing level. In this section, we present a model instantiation involving one manner how experts construct project representations and how non-experts can access and explore knowledge about heritage projects.

Models should demonstrate flexibility as an important feature of sociomaterial design. Flexibility is enacted in both the design-time performed by designers and run-time executed by users. Flexibility in design-time and run-time means the ability to modify both the artifact and the design process in order to fit needs in relatively short time as they are embedded in a context in which adjustments are allowed (Leonardi, 2011). Most of the flexible design occurs in run-time, when new requirements that were not considered during planning time emerge (Kurz, Schmidt, Fleischmann, & Lederer, 2015). The sociomaterial design enacts a discretional and emergent decision-making process that makes it a knowledge-intensive process. This process is characterized by an array of activities that cannot be predefined and repeated as is possible with activities in a sequenced workflow (Davenport, 2005; Van der Aalst, Weske, & Grünbauer, 2005). Instead, those activities evolves in dynamic and contextual situations and depends on ad hoc decisions by knowledge workers (Mestdagh, 2015).

KMS designers traditionally use boxes and arrows and follow a control flow to represent sequential steps in a workflow control to design and configure a system and this prescriptive way limits designers in perceiving affordances from design materials available and bounds flexibility in design time modelling. There are different modelling languages to design KMS such as ontology-based modelling, object-oriented notations reflected in knowledge engineering methodologies such as CommonKADS, Knowledge-based systems and multidimensional data modelling (Abdullah, Evans, Benest, & Kimble, 2005; Dutta & Madali, 2015; Pigott & Hobbs, 2009). The modelling design process for KMS can be based on existing workflow modelling solutions such as BPM, Petri nets, Event-Driven Process Chains and UML Activity Diagrams (de Albuquerque & Christ, 2015). However, these modelling languages are limited because first, they are too rigid due to imperative information processing (Mestdagh, 2015); second, they are focused on automation of business process (Kurz et al., 2015); third, the notations are too restrictive and struggle with changes during process execution; and four, the languages consider a separation between design-time and run-time (Hauder, Münch, Michel, Utz, & Matthes, 2014).
Accordingly, we propose Case Management Model and Notation (CMMN) language as a way of modelling sociomaterial design processes for KMS. Detailed specifications of CMMN are included in (Object Management Group (OMG), 2016). CMMN is a declarative process model in which designers describe ‘what’ is allowed and disallowed in the process; versus imperative modelling in which designers describe ‘how’ to do the process (Marin, 2016). Declarative modelling techniques partially fit sociomaterial thinking because designers can determine the material properties of a system (in design-time) as they are common to each person who encounters them (Leonardi, 2011) but also, both designers and users (in run-time) can configure and reconfigure some system components flexibly as they perceive new affordances or constraints from technology. In CMMN, what is modeled can be disabled at execution time by case workers according to contextual changes. In CMMN, systems can be either completely structured or variable so that deviations of the specified routes in the processes are possible (Van der Aalst, 2000). In run-time design, many knowledge workers can produce several instances of the KMS, and so complexity and high variation in outputs are easier to implement with CMMN compared to traditional workflow management (Tran, Pucher, Mendling, & Ruhsam, 2013).

In CMMN, a model may have multiple cases, and each case is described by a case plan. The case plan model contains the case model and encloses the whole diagram. The case worker decides which tasks must be performed or not in the case instance for a particular context. A task represents the execution of actual work. There are four types of tasks, namely non-blocking human task, blocking human task, case task, and process task. Task can be discretionary, which means that the case worker may decide an ad hoc manner of developing activities. Stages are containers that divide cases into subdivisions. Milestones represent accomplishments during the execution of the case instance. Sentries defines dependencies or the direction of the sequence flow. An event-listener waits for something to happen, usually to then trigger a new sequence flow. A case file item represents a data file or document that contains information that is relevant to the case. A connector between CMMN elements defines a relation. An entry criterion or exit criterion defines the sequence flow direction or association. A planning table signifies that discretionary tasks are present. A plan fragment allows grouping mechanism for discretionary items. Decorators indicate certain characteristics of the item such as manual activation, repetition, requirement and auto completion (Marin, 2016; Object Management Group (OMG), 2016).

A Case has two distinct phases, the design-time phase and the run-time phase. The Figure 5-1 describes these concepts. During design-time, designers engage in modeling, which includes defining stages or tasks that are “required” and always part of pre-defined segments in the case model, “optional” so not required to complete for the scope to terminate, and “discretionary” tasks that are available to and instantiated by the case worker and applied at his/her discretion. A process model specified at design-time serves as a case management plan for execution of a case (Jansen, 2015; Object Management Group (OMG), 2016). In the run-time phase, case workers create and execute the plan, particularly by performing tasks as planned, but the plan evolves and changes dynamically as case workers select and execute discretionary tasks, instantiating the case in run-time (Jansen, 2015; Object Management Group (OMG), 2016). This form of runtime flexibility allows case workers to respond to emergent challenges as it is impossible to predict the whole action possibilities people will perceive from the system. The CMMN modelling language
follows the idea of templates that can be instantiated and incrementally improved by end users at run-time (Haude, Münch, et al., 2014). Changing the case behavior through ad hoc execution of discretionary tasks in run-time means creating new instantiations of the artifact (Jansen, 2015) affecting information models but not design models.

The sociomaterial design should be supported by design-time modelling specification but mainly by run-time specifications to be able to model dynamic knowledge sharing processes. Run-time flexible design allows designers and users to respond to contextual challenges or new requirements that emerges as people move through different sociomaterial practices that cannot be considered fully during planning the design processes. In this sense, CMMN currently comes closest to affordance and constraint theories which are the core in ad hoc design. This modelling technique allows KMS designers and users to intuitively, interactively, and flexibly perform ad hoc changes to single system components, while ensuring that the result will still be able to execute properly (Guenther, Reichert, & Van der Aalst, 2008). Some ad hoc adaptations may represent instances of contextual changes in both the designers and user’s perspectives, but the majority of ad hoc adaptations occurs during the run time of a case (Kurz et al., 2015). CMMN is not dictating designers and users a predefined course of action but provides them with proper knowledge about making design decisions (ad hoc design) as they perceive possibilities for action from material properties of the KMS and its components (second-order design).

5.3 A KMS prototype as an instantiation the reference architecture
A comprehensive overview of the sociomaterial design process followed to build the KMS prototype for RedPHI is presented in Figure 5-2, including the interaction among the different design stages. Some of these stages were modelled with CMMN language in order to guide
designers while instantiating the reference architecture. For each one, we present the specific process activities performed to design the affordances for DG1, DG2 and DG4 and to include the design features listed in Section 4.4.

![Diagram](image)

Figure 5-2 An overview of the sociomaterial design process of a KMS

### 5.3.1 Eliciting Sociomaterial design requirements

Part A in Figure 5-2 presents the process stages we followed to elicitate requirements in the sociomaterial design process of a KMS. This process allowed us analyze and understand sociomaterial practices from the real context of RedPHI. The set of sociomaterial design requirements presented in Section 4.3 were elucidated through exploration of conversations between and within sociomaterial ecosystems in which conversations between people, between people and technologies and among technologies themselves were the main focus of the exploration. The Figure 5-3 presents the process to elicitate requirements in our reference architecture.

Observation was the key stage for understanding the field action. In this stage, we determine the level of detail for observation of the application domain, reflecting through the observation process upon insights about how sociomaterial practices are enacted. Observation practices can be different according to the application domain characteristics and so observation techniques and tools used in field action can change. In this part, consultative activities and feedback from domain experts were appropriate to increase understandings of the heritage domain and served as an accuracy test for the observation process.

Because sociomaterial relations between agencies are temporary and in order to discover design requirements, it was important to figure out sensibility of the sociomaterial ecosystems regarding to contextual changes, analyzing the current dynamics of sociomaterial ecosystems in some domain scenarios. At this point, information about historical imbrications and feedback from domain experts were gathered, leading to deepening the specific domain requirements that should be supported by the KMS. Once the field action was observed and fully understood, we generate a document with requirements specification as presented in section 4.3.
5.3.2 **Contextual dimensions of the sociomaterial practices**

The Figure 5-4 presents the contextual dimensions of the sociomaterial practices in the application domain that have to be identified and explored for eliciting requirements and designing the KMS. The contextual dimensions enact the possible variation points in which each instantiation of the reference architecture can be different. Those contextual dimensions determine how people perceive different and multiple affordances or constraints from material properties of technology (Doolin & McLeod, 2012; Leonardi, 2011). The sociomaterial practices can be understood by tracing the context and practices within which an object found itself, finds itself or will find itself (O’Raghallaigh, McCarthy, & Adam, 2017).

A contextual change occurs when location, roles, time, situation, interest, utilization, etc., is modified. In this regard, some relevant aspects of the sociomaterial context are: ‘what is the domain object’, ‘what sociomaterial practices are performed about the object’, ‘who participates in those practices’, ‘what materials constitute ecosystems in the sociomaterial practices, ‘who interacts with whom’, ‘how are people coordinated’, and ‘where and when are sociomaterial practices performed’. This aspects respond to calls for alternative approaches to design IS devices as a representation of reality but starting from conceptualizing and theorizing about what reality means, how it is understood and how to translate it to manageable forms such as data, structures, algorithms, etc. (Boell & Cecez-Kecmanovic, 2012; McLaughlin, 2015). Therefore, a KMS represent a real view coordination for KS in heritage projects, which becomes enacted in a particular reality once the KMS is instantiated by expert and non-expert users.

Putting together the contextual dimensions, we reached an extensive definition of the sociomaterial context in which sociomaterial practices at RedPHI are developed as well as a complete set of observable and relevant characteristics of the interaction between agencies. Each
contextual stage is composed by at least one required action to observe the contextual variable as well as a set of discretionary tasks that can be instantiated at any time and frequency, in order to reach deeper understandings and insights about the contextual dimension. Both stages, elicitation of requirements (part A) and designing the KMS (part B), were continuously related with at least one contextual dimension, but most of them involved more than one getting into deep details of the situation enacted during imbrication processes. Even though our set of dimensions group the larger quantity of contextual variables, it was determined from specifications in our application domain, so that further instantiations of the reference architecture should update or adjust this stage as well as tasks inside each plan fragment.

Understanding the contextual dimensions of the application domain helped us to keep in touch with the problem relevant environment and we used this information for refining and revising the chosen solution path. However, as with application domain activities, the design process itself constitutes a sociomaterial practice with specific contextual variables related with the personal ecosystem of the designer. The distinction between the application domain context and the designer context elucidates the dualistic and ecological approach of contextual dimensions in sociomaterial design. Initially, both contexts are separated but when the designer starts to observe and explore the application domain in order to identify design requirements, this design context becomes embedded in the application domain context. In this approach, adaptation and analytical distinction between the two contexts are possible. The careful interplay between contexts, problem-space features, and constructive solutions constitutes an ideal framework for exploring sociomaterial practices and capturing sociomaterial design knowledge as well. In this stage, we specifically determined some of the contextual dimensions of designers in the sociomaterial

![Figure 5-4 Contextual dimensions of sociomaterial practices](image-url)
design process for the KMS at RedPHI. Specifically, we determined who was able to design what, evaluated resources and capabilities for design activities and identified routines and events in the design team.

5.3.3 Conceptual modelling

In part B of Figure 5-2, designers match material properties of available technology with design requirements. In doing so, it is important to formulate the conceptual model of the system, to identify building components for the KMS and to design the system. Conceptualization is the first step when designing a KMS. The conceptual model provides a first analysis of challenges and concerns for KMS design and the parameters that are needed to arrive at acceptable KMS from the sociomaterial design. Following the design requirements, we determined the design criteria and strategy to be used to represent the system. Additionally, the specification of the design scope considered contextual dimensions of designers, dimensions of the contextual environment and contextual dimensions of technologies. In this regard, some feedback from domain experts lead to fit properly design requirements with design prospective, and so designers were able to obtain greater understandings over the design purpose. Reflecting upon the ontological and epistemological design position was helpful to evaluate the conceptual model regarding to sociomaterial philosophical assumptions. The Figure 5-5 presents the conceptual model for a sociomaterial design process of KMS.

![Figure 5-5 Conceptual model of the sociomaterial design process](image)

5.4 Building the KMS prototype

We developed an initial KMS, building on the design guidelines, the design requirements and insights from the three DSR iterations. In doing so we developed a framework to guide implementation. In consist of three parts: definition of proper technology types according to specific domain requirements; selection of KMS components that can meet design requirements and design guidelines; and the assembling process in which tools are integrated in a single KMS. The whole KMS was built with open source technologies which are available for everyone at no additional charges.

5.4.1 Selecting the KMS building components

The assembly process started by specifying the proper technologies for the system according to specific requirements for RedPHI (Section 3.8), design requirements (Section 4.3) and design features (Section 4.4). The knowledge sharing practices in heritage projects at the RedPHI points to coordination activities where multiple and heterogeneous parties with different roles and competences become involved over a period of time in diagnosis and intervention of a heritage
object. The actual characteristics of the work in the heritage domain also implicated several artefacts at different stages to suit specific purposes. As for the venues available to share knowledge, there is a topology of technological tools that were appropriate to assemblage the KMS for RedPHI projects. Specifically, the KMS required four categories of artefacts as follows:

a) A project management system to support heritage experts across the entire project lifecycle, enabling collaboration and keeping the project information organized while they are using their personal artifact ecosystems. Flexible configuration is desirable to support experts in ad hoc design activities fitting heterogeneity in projects and actors as well as uniqueness of the heritage objects.

b) A tool that helps heritage experts find and set up all necessary resources needed to perform a specific task. It is meta-knowledge required to manage, understand and use information, devices and services distributed across personal ecosystems that are part of the ongoing heritage project.

c) A mobile service that allows people (experts and non-experts) to complement basic information of a heritage object with knowledge about it. It is a way to enhance the knowledge sharing and discovery processes in different contextual settings offering an enriched experience regarding the material properties of the heritage object situated in a specific geographical location.

d) A service that governs the connecting process in order to track the other service components that make up the KMS.

The Figure 5-6 presents the selection process for the KMS components according to the topology determined. In this stage, we conducted a technological exploration in order to identify the existing and available toolset within each topology defined to build the KMS. Access, availability, support, maturity and traceability were some criteria used to perform the technological exploration. Additionally, the exploration aimed to determine what functionalities can help designers to support design requirements. Designers and domain experts jointly identified and explored the material properties of available technology, focusing on scope, service purpose, and intended use among other factors. An analysis of further alignment between material properties of different tools, was appropriate to ensure consistency and coherence in the design perspective. An additional test of material properties regarding to domain characteristics produced preliminary insights about usefulness and ease-of-use perceived by expert’s domain. Feedback from domain experts was valuable to ensure fitting and understanding of the KMS design. In addition, we determined the configuration space where personal artefact ecosystems of RedPHI experts are connected, enacting a meta-coordinated artifact as we postulated in DG 2. Finally, we evaluated the scope of the material properties of selected tools including the observation of affordances such as adaptability, flexibility, and customization.
Consequently, we selected the following set of tools to build the KMS:

a) The KMS includes a project management system to support heritage experts across the entire project lifecycle, enabling collaboration and keeping the project information centralized and accessible while they are using their personal artifact ecosystems. This component was supported by using the Open Science Framework – OSF platform which allows coordination for KS activities (Foster & Deardorff, 2017; Potterbusch & Lotrecchiano, 2018) and it was configured in several iterations of the prototype. OSF affords several material properties of those mentioned for DG1 and DG2 in Section 4.4.

b) The KMS contains a visualization tool that enable meta-knowledge required to share knowledge distributed across personal artifact ecosystems. For this purpose, we used an online network-visualization platform called KUMU (Kumu, 2018). This KMS component enables knowledge discovering and sharing (de Moor, 2017) through network maps that fit design features of DG4.

c) The KMS comprises a mobile service that allows people to attach knowledge to physical places by writing personal stories or adding pictures. We used WallaMe (WallaMe Ltd, 2017) as an in-situ and contextual representation of KS practices (Munters, 2017) that meets the DG1. This mobile application makes knowledge accessible in the same form and place as the original display after the expert has finished his or her fieldwork. Using augmented reality, WallaMe supports the in-situ representation of KS practices that meets the DG1.

d) As OSF, KUMU and WallaMe are individual and independent tools, it was necessary to develop a middleware interface in order to compose them as a single KMS enacting a meta-coordinated artifact.

The three components selected to build the KMS are open source applications, are agnostic as they do not meet a specific discipline, and have been used in different activities in the heritage domain.
### 5.4.2 Assembly process

The Figure 5-7 presents the process followed to build the KMS. This stage involved design, adaptation and adjustment of the KMS prototype. In doing so, a set of required tasks were executed during the design process such as configuring tools; building, evaluating and modifying the prototype; generating system adjustments; and determining feasibility of design decisions. Meanwhile, a set of discretionary actions coped the design process with flexibility and ad hoc design. Ad hoc tasks included developing, coupling and changing tools; determining material properties of the system; determining possible affordances and constraints of the tools; fitting design criteria; and getting feedback from domain experts. The milestone of this stage was to produce a minimum viable product embodied in a functional prototype that can be tested and evaluated.

![Figure 5-7 Building the KMS prototype](image)

Each tool was initially tested separately in order to evaluate material properties afforded by each one, adaptability and flexibility levels, and configuration issues to integrate the KMS. Some tests were carried out to determine interoperability aspects between the three components, determining the specific needs to be programed in the middleware interface and what others should be supplied by native configuration of the components. For instance, WallaMe can be easily integrated with OSF by using a cloud service such as Dropbox or Google Drive, and it was not necessary to program additional services to ensure information flow between them. Most of the middleware programming activities were dedicated to connect OSF with KUMU due to non-existent data integration between the two components. The script was developed in MS Access and it gathers data from OSF by using the API and then, exports it to Google Sheets in a specific data structure determined by KUMU as both are integrated. Appendix E shows some details of the middleware interface. In this stage, KMS designers and domain experts jointly determined some common scenarios of use with distinct combinations of building components that meet different project activities in practice. Next, we present an overview of some scenarios and the suggested combination of tools (a) OSF, (b) KUMU, and (c) WallaMe.
In research projects, the starting point is to perform a literature review about the heritage object in order to get a generic panorama of the context and then they go to the object site to collect field information. Here the sequence could be a-b-c.

In consultancy projects, the first activity is to visit the object site to evaluate, on a preliminary basis, its conservation status and then they collect different materials (documents, pictures, architectural drawings, geolocation plans, etc.) in order to contrast field observations. In this case, the sequence could be c-a-b.

If the current heritage project is based on knowledge about prior projects stages, and if the project team experts of the current stage were involved in that previous explorations, they do not need to visit again the object site, but they start reviewing prior insights and making decisions over new requirements. The sequence in this scenario could be a-b.

Regarding the later scenario, if the project stage involves an object which has not being checked by heritage experts beforehand, thus the sequence could be c-a.

If the experts are working in the field collecting data, they could use just c, but if they are having a budget committee to make decisions about first-aid restorations then they could use the sequence a-c. However, if multidisciplinary experts are debating about the ontological perspective to intervene the object which are at risk of collapse, the sequence could be a-b.

5.4.3 Conceptual design of the KMS prototype

Conceptual design represents a graphical description of blocks and their relations that compose a system. The conceptual design is defined as “an early stage of design in which designers select concepts that will be employed in solving a given design problem and decide how to interconnect these concepts into an appropriate system architecture” (Rzevski, 2003). This section describes the conceptual design of the KMS for sharing knowledge between heritage projects. Because of the complexity of the KMS prototype and the coordination approach followed to build it in which we integrated existing tools to make the artifact as a KMS, some of the technologies selected in section 5.4.1 can perform different functions in more than one layer. This is particularly important when flexibility and adaptability are the focus of design. The KMS conceptual design has three main layers such as process, management, connection and information. Each layer has a specific functionality designed for management of one particular coordination task for sharing knowledge. The conceptual design of the KMS prototype is shown in Figure 5-8.

Interaction with the web application is enabled by OSF and KUMU which are capable of managing and visualizing information by using web services. Mobile Applications allow domain experts to share in-situ information with geographically distributed people through the KMS. Domain experts from RedPHI can share knowledge between heritage projects through the KMS with other team members by using the web and mobile applications. External users are able to use the web application to explore public knowledge in the KMS including information shared from mobile applications. Internally, the system is composed of the following components:

- **Knowledge layer** is the set of KM process responsible for searching, discovering, retrieving and sharing knowledge about heritage objects and their related projects.
- **Managing layer** manages the whole knowledge regarding to current or past heritage projects including content and context information. It involves in-situ and project management, visualization and interface between components.
- **Gateway** provides technological flexibility for domain experts by allowing interoperability between competing and diverse ecosystems.
- **Information layer** represents the knowledge spread through different and diverse technological ecosystems which are connected in the gateway.

Figure 5-8 High-level conceptual design of the KMS prototype

Arrows represent interconnections between all the composing blocks of the KMS. All the connections, except inside the managing layer, are bidirectional. As the system affords people to move between individual and group workflow, information flows across the information and managing layers in order to keep updated and complete the project knowledge. All the KM processes are supported by the KMS, and so the managing layer include some material properties that afford experts with possibilities to manage knowledge about the heritage projects. Both domain experts and non-expert users interact with the KMS components through the web and mobile applications in order to gather and provide knowledge. With regard to unidirectional connections in the managing layer, they represent how information flows between the selected tools composing the KMS.

### 5.4.4 Description of the KMS Prototype

The purpose of this section is to present the KMS description in order for designers and the domain experts’ community to understand its fundamental structure and functioning. We specifically describe the implementation and configuration of the building components. Figure 5-9 shows the relation between tools composing the KMS as explained in Section 5.4.1. Most of the knowledge about heritage projects at RedPHI used to build our KMS prototype is public and it is available in OSF by clicking this link: [https://osf.io/g8hqd/](https://osf.io/g8hqd/). Moreover, knowledge and network
Maps in KUMU are also public and they are available in [https://kumu.io/nestornova/redphi-project](https://kumu.io/nestornova/redphi-project).

![Diagram of selected tools composing the KMS](image)

**Figure 5-9 Selected tools composing the KMS**

- **Accessing knowledge in the KMS**

In KMS, knowledge can be accessed by several ways. In OSF, knowledge is accessible through using some material properties such as granting continuous access to the information by adding a group of collaborators within a project with different permissions levels, who can access and modify the work. In addition, access is supported by making public a project or component (a sub-project below the top-level project) for everyone who can explore it even if they are non-experts. Each project or component contains a wiki that describes the current state of the activities but also a comment pane is available to discover new insights. The project information is centralized in the project management tool allowing full accessibility to project insights and lessons learned data base for all expert and no-expert actors which is crucial to leverage KS between heritage projects. This open and accessible knowledge is the basis to reach effective utilization of knowledge in new projects. Figure 5-10 shows some project information accessible by the KMS.

In KUMU, knowledge is accessed through public network maps which contain the most relevant information of the project managed in OSF. This map allows access to several knowledge resources such as projects, components, contributors, files, tags and linked projects, including relationships among them. Each knowledge resource is presented through infographics which represents detailed background information about what is mapped and an overview of relevant information available in OSF for each element. For instance, infographics of projects and components contain: description, representative picture, link to OSF project, creation and updating dates, contributors, wiki content and tags. Infographics of files contain description, creation and updating dates, current version, storage provider, download link, and tags. Infographics can be showed completely in the left side of the screen by clicking in the element map or partially by hovering the cursor over the node. In addition, relations between map nodes also contains complementary and contextual information describing the type of link. Figure 5-11 shows the infographic of a project in the visualization tool.
In WallaMe, knowledge is accessed through public walls located in a specific geographical location. Through the app, people can access to an augmented reality with pictures and text posted by experts in the heritage object location. As this knowledge is enacted in a digital material, this can be also accessed in OSF and KUMU through a web navigator in a different location with the same content that the mobile app. Figure 5-12 shows details of knowledge available in WallaMe.
• **Accessing people in the KMS**

In KMS, knowledge from heritage experts can be accessed by making available some profile information about them. In the KMS, project contributors must share basic information such as biography, education, employment, social media, personal picture, email, core skills, public projects, among other. This information affords awareness of experts’ relevant expertise enhancing social capital in the heritage domain, but also it is public to everyone who wants to contact an expert, ensuring timely access and enabling knowledge sharing. Personal profiles are presented as an infographic in OSF and KUMU. In OSF, the description section includes the list of experts working on each project and component. Ultimately, this material property promotes knowledge sharing between heritage projects by allowing to reach experts and establishing new connections. The personal profile presented in OSF is showed in Figure 5-13.

![Figure 5-13 Personal profile in OSF](image)

In the visualization tool, nodes enacting heritage experts are linked to every material with which they are participating and some additional information is shown in those relations. For instance, connections between heritage experts and projects show the role of the participant and their corresponding activities being performed. The personal profile visualized in KUMU is shown in Figure 5-14.
Centralizing information in the KMS

In KMS, knowledge about heritage projects is centralized through OSF. Several storage technologies such as institutional repositories and web services and personal or group cloud services comprise an important part of the knowledge in a project. In this sense, OSF acts as a gateway allowing to connect different add-ons that afford information access, exchange and sharing by mixing and matching resources stored on personal cloud services, locating and making all of them available in one place for experts inside the project or for everyone as information can be made public. As knowledge about a heritage project is highly dynamic and contributors of a project can vary according to the current development phase, add-ons can be connected and disconnected on demand. In addition, other material properties such as updating and editing also extends the possibility to reach a seamless workflow in the project. The KMS maintains a record of previous versions of files which are available with details and the corresponding download link for each one. Information such as text, tables, pictures and pdfs can be open directly in OSF and text files can be edited too. External links to institutional services and website can also be connected in the OSF. Figure 5-15 shows the file detail page with the list of all connected add-ons and their content respectively.
Retrieving knowledge from the KMS

In addition to knowledge access and centralization, the KMS afford material properties for indexing, categorizing and clustering the project information. As the KMS contains several information about the heritage objects and projects, and this information is stored in personal artifact ecosystems but centralized in the KMS via a gateway, the KMS includes a tagging service in which experts label their knowledge resources with arbitrary words, so-called tags. By using the tagging system, experts collect, share, and annotate digital materials, projects, components and files. Heritage experts assign their own tags freely to personal or shared information stored in both OSF and KUMU. Tags allows to filter and retrieve information according to individual preferences. Through tags, OSF allows retrieving all tagged resources with a specific word or combination of words inside a project but also it supports an extended search by recovering additional tagged materials within the OSF data base. This material property affords unveiling relevant information of external projects performed by other researchers who eventually could share knowledge with local experts. Therefore, the tags act as a coordination mechanism for materials but also for people. In Figures 5-16 and 5-17 we present the module to assign tags and the search service respectively.

Figure 5-15 File detail page in OSF
In KUMU, tags are visualized as nodes connected to digital materials. There are two important characteristics of this material property. First, tags can be shown as a tag cloud that is essentially a map of the relationships among tags, each one, in turn, representing the contents of some data collection (Vian, Liebhold, & Townsend, 2006). The relative prominence of the tags is represented by size which demonstrate the number of materials to which a tag has been applied. This feature is especially useful to make people aware of existing vocabularies about heritage objects and to make visible resources to other participants. Figure 5-18 presents the tag cloud in the KMS.

Second, connections between tags and materials afford valuable sociomaterial information about the context of tagging such as who tagged a resource, where, when and why, recent activity of the taggers in the KMS and last five tags assigned by them. By using this contextual information, it is possible to establish new sociomaterial relations, for instance, context can support discovery of groups of heritage experts using similar vocabulary to label a project, or periods in which a set of words are more relevant than others. Figure 5-19 presents one example of a tagged resource and the contextual information of the connection.
Figure 5-18 Tag cloud in the KMS

Figure 5-19 Tagged resources and contextual information of the connection
• **Controlling access to the project information**

The KMS supports controlled access to the project information as some of it can be sensible or considered as private. In OSF, access of contributors to project or component information is controlled by the project manager according to the specific role performed for every expert. Each component can include different people as contributors due to many disciplines, roles and activities. The project information can be accessed totally or partially by following rules defined by the leaders who regulate the information specifications that can be shared among the project team and made public for everyone who wants to explore it. In addition, OSF affords the possibility to make public the overall project or some parts including folders and files inside it. This decision can be made by the leader of each project or the general manager. Privacy settings can be changed discretionally at any time. In KUMU, maps can be converted from public to private and vice versa, affording another way of controlling. Figure 5-20 presents the two ways to control access to project knowledge.

![Figure 5-20 Access control to the information project in OSF](image)

• **Setting the project structure and organization**

The KMS affords flexibility by allowing to configure and reconfigure both functions and content according to each project specification. The project management tool is open to meet people and project requirements and so knowledge can be organized and structured in many ways. For instance, experts can write as many wikis they need to communicate knowledge and each one can include text, pictures, videos, links, etc. Tags are freely assigned to projects, components and files, and there is no a controlled vocabulary to mark a material. A different reference list can be associated to distinct components in the same project affording differentiation between disciplines, phases, stages, etc. However, flexibility is mainly represented in the KMS by affording dynamic and ad hoc design of diverse configurations to manage project and component information. A combination of projects, components and folders affords experts with plenty of possibilities to design and configure a specific structure to fit the project needs. For instance, information about a consultancy project can be structured by using a component for each project phase (Figure 5-21a) and inside each component, information can be managed through folders for different tasks (Figure 5-21b). Moreover, a research project can be managed by creating only folders for data, analysis, instruments, procedures, etc. (Figure 5-21c). But the same research project could avoid those subdivisions and all information could be stored in the main folder of OSF. Also it is possible to design and organize a project or a component with a blended structure of projects, components and folders (Figure 5-21d). This KMS feature specifically supports changes in routines as heritage experts can be a contractor, consultant, professor and researcher.
in different projects at the same time so that they need to design different structures and navigate daily across them.

- **Visualizing knowledge to make decisions**
  
The KMS affords material properties to visualize knowledge to make new decisions. KUMU is the main tool to show information about heritage experts, projects, components, files, tags and connections between them, as a network map. Each node contains specific information and details about content and context of the heritage projects. This node type has a particular structure to present the information, so that infographic of people contains biography and contact data; project, components and linked projects include description, pictures, wiki content, contributors, etc.; files contains dates, versions, storage provider, etc. As the KMS is composed of three independent tools, we ensure interoperability among them by exporting project information from OSF to KUMU but also in KUMU each node includes a link to get more details of its content in OSF. In addition, all nodes are interconnected by dotted lines which, in turn, are labeled according to the type of relation. For instance, connections between projects and people are labeled with the
role of the expert in each project; connection between files and components are labeled as “is a file of”; connections between resources and tags are labeled as “tag project” or “tag file” depending of the type of node. These labels facilitate the distinction between different types of connections and afford people with additional content to filter information in the map. Each connection includes additional details about the relation enacted, for instance, connections between projects and people contains the role and the activities performed in the project. Ultimately, visualization fosters a sociomaterial understanding of the work by keeping together knowledge resources with contextual information. Figure 5-22 shows an example of visualization about a specific project.

In addition, the KMS offers different possibilities to filter the information according to the cognitive background and needs of people. A search panel helps user to find a known resource; a showcase allows to show or hide elements and connections based on the information they contain directly on the map; a filter menu affords advanced properties to hide certain elements and connections using checkboxes; and a color legend makes sure people can easily understand the information available on the map. Those filtering functions afford experts and non-expert people with a flexible visualization architecture to meet individual or team knowledge needs.

Visualization is also supported through WallaMe as people can visualize public knowledge in situ and experts can share knowledge easily with the project team. By using augmented reality, this KMS component afford experts with possibilities to share notes, pictures and text in a specific geographical location. An initial picture taken by the expert is used as the base to augment knowledge about a heritage object or an element inside it. By entangling physical objects with digital materials and human agencies enacted by people exploring the walls, a knowledge network is created to promote knowledge sharing. All the walls can be made public for everyone with the
app installed in the smartphone and located in the wall place or can be shared directly via social
media with a specific group of people, such as the project team, located in other geographical
location to be explored in a laptop. Also, all the walls can be automatically upload in OSF through
a connected cloud service and then visualized in KUMU. The description of each WallaMe node
in KUMU contains the link to open the wall directly in the WallaMe web page. Figure 5-23a shows
an example of an in-situ visualization of a heritage object through the WallaMe app and Figure 5-
23b presents a wall visualized through a web browser in a different location.

![Examples of walls in WallaMe](image)

(a) Mobile app version  (b) Web browser version

Figure 5-23 Examples of walls in WallaMe

5.5 Evaluation of the KMS prototype

In Chapter 2, the sociomaterial approach was proposed as a way to tackle the lack of design
guidelines in IT-artifact design processes. In Chapter 3, the results of the case study at RedPHI
laid out the specific requirements needed to overcome the coordination issues. Chapter 4
presented and discussed the reference architecture including meta-requirements and design
guidelines for sociomaterial design. In Chapter 5, a KMS prototype was presented as an
instantiation of the reference architecture. In this section, the validation of the KMS is presented.
For a description of the scientific and practical contributions of this doctoral research, readers are
referred to the Epilogue (Chapter 6).

5.5.1 Overview and planning

Evaluation provides information about whether the artifact solved a problem as well as essential
feedback to reach enough quality of the design process and the design product under development
(A. R. Hevner et al., 2004). During the evaluation, the artifact must demonstrate through well-
executed evaluation methods the utility, quality, and efficacy of the designed artifact. In doing so,
the third DSR guideline proposed by Hevner (A. R. Hevner et al., 2004, p. 85) posits that the
design artifacts can be evaluated in terms of “functionality, completeness, consistency, accuracy,
performance, reliability, usability, fit with the organization, and other relevant quality attributes”.

As the reference architecture is the highest level of abstraction, an instantiation of it (KMS
prototype) was developed for the specific context of the heritage domain. A direct evaluation of
the reference architecture is very difficult due to its level of abstraction. We developed a prototype
to prove the technical feasibility of the architecture and evaluate it via the acceptance of the KMS by a group of users and experts of the heritage domain. In addition, as the process structure and components are based on the design guidelines, the guidelines are then also evaluated via the evaluation of the acceptance. Notice that implementation guidelines are suggestions to IT designers and so these are not the focus of the evaluation, however we show how each affordance and design feature was enacted in the KMS prototype.

One of the main characteristic of DSR is that design is an iterative activity that include one or several evaluation phases providing essential feedback to the construction phase (Gregor & Hevner, 2013). In this section, we present the evaluation of the KMS prototype through three activities. First, we verified the correctness of the prototype models; second, we verified how the implementation guidelines are embedded in the KMS prototype; and third, we conducted a study of KMS adoption through different groups in order to validate whether the reference architecture, instantiated through the KMS prototype, allows to improve coordination for knowledge sharing between heritage projects.

We distinguish between verification and validation. In our design science context and following definitions posited by Sargent (2013), verification is defined as ensuring that the instantiation of the reference architecture in a KMS and its implementation are correct; complementary, validation means the substantiation that the KMS within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the system. In this sense, the verification process was applied to the prototype models and the implementation guidelines and the validation process was executed over the KMS adoption by domain experts.

5.5.2 Checking correctness of the prototype models
Currently, there is no a standard validation technique for CMMN models (Ruiz Herrera, 2017) and so this task must be performed manually. From the knowledge base on BPM, Marin et. al proposed to use complexity metrics to evaluate and verify CMMN models (Marin, Lotriet, & Van Der Poll, 2014, 2015), however there is still a lack of empirical use of this metrics with real models. Other scholars (Hauder, Pigat, & Matthes, 2014; Marquard, Shahzad, & Slaats, 2015) argue that simulation could support validation in declarative processes in adaptive case management, but it is challenging due to expensive coding implementation (Hintzen, Van Kervel, Van Meeuwen, Vermolen, & Zijlstra, 2014, p. 1). Some CMMN modelling suites such as Camunda and Trisotech include animation modules as a way to interact with the created case, however it does not produce enough information to verify consistency and, as far as the researchers are aware, literature about their empirical use is limited.

In order to verify correctness, completeness, consistency and unambiguity (Balci, 1998) of our CMMN models, we conducted a desk checking test. Desk checking is a manual test that designers can use to verify logic of programs before launch (Adrion, Branstad, & Cherniavsky, 1982). It attempts to check requirements, design specifications, and code by hand as the program is developed (Jan, Shah, Johar, Shah, & Khan, n.d.). The main advantages of desk checking is that defects can be easily detected and corrected in early stages at same time (Nidhra & Dondeti, 2012). In order to perform the desk checking test for the sociomaterial design process model and taking in account that there are no confidence techniques for CMMN models, we take as a reference the
verification and validation framework proposed by Sargent (2009) in the context of simulation modelling. We conducted a conceptual model validation, computerized model verification, and operational validation until sufficient confidence was obtained that our model can be considered valid for enacting the sociomaterial design process.

**Conceptual model validation.** The conceptual model validation determines if the theories and assumptions underlying the conceptual model are correct and that the model representation is reasonable accurate (Sargent, 2013). A conceptual model validation was performed in order to determine that the sociomaterial design guidelines and design features are enough represented in both the design model and the user model. In this stage, errors were found in the conceptual model during the initial two versions and they were revised and conceptual model validation performed again, reaching a consistent version. The validation technique used in this stage was traces. A tracking analysis of entities through each submodel and the overall model was performed in each iteration in order to determine if the functioning logic was correct in both the sociomaterial design process model and the prototype instantiation model and if the necessary accuracy was obtained. Accuracy means how the way of working is properly represented in the KMS prototype. Therefore, validation of the design process went through verification of accomplishment for each design guideline, but also, we tested that the prototype model was a correct representation of a KMS designed from sociomateriality.

**Computerized model verification.** Computerized model verification ensures that the computer programming and implementation of the conceptual model are correct (Sargent, 2013). The sociomaterial design process model was built using the Camunda suite which is an open source platform for workflow modelling that supports CMMN language. Models built in Camunda are developed following the OMG standard for CMMN modelling (Object Management Group (OMG), 2016) and using the Extensible Markup Language (XML) language (Bray, Paoli, Sperberg-McQueen, Maler, & Yergeau, 1997). We verify that models are error-free in two ways. First, we checked the XML code using the markup validation service of W3C in order to test technical quality of the code. Second, we use the Camunda Play web service (Camunda, n.d.) to test the behavior of small parts of the model using clicking prototypes, which allow designers to verify if the instances of non-discretionary stages or tasks are enabled, active, completed, terminated or available according to the design process rational.

**Operational validation.** This validation stage determines if the model’s output behavior meets the model’s intended purpose over the domain of the model’s intended applicability (Sargent, 2013). As the model represents a design process, the most appropriate technique to validate operation is to test the design process through the design and development of a KMS prototype in the heritage domain, which we present in Section 5.4. Following this operational validation, we reach a high degree of confidence in the sociomaterial design process model because the KMS prototype was tested with real users producing feedback for modeling tasks. As several design iterations were necessaries until the launch of a functional KMS prototype, diverse model adjustments were allowed, performing an ongoing improvement of the sociomaterial design process models.
5.5.3 Verifying the implementation guidelines

Problem solving must produce new knowledge and, in this thesis, it corresponds to design knowledge that leads designers to develop a KMS from sociomateriality. As we posited in Section 4.4, each design guideline involves a set of affordances and design features that could be designed and embedded in the KMS in order to afford people with certain material properties to improve coordination in knowledge sharing activities from the sociomateriality approach. Each design guideline represents a set of design hypothesis that must meet specific requirements. Affordances, in turn, are operationalized through design features that represents material properties of the KMS, namely functions. Both affordances and design features help IT designers to implement a KMS from sociomateriality. This design knowledge can be considered as a design theory in a broad sense, not like biology or physics, but as new design knowledge that can be transferred from designer-to-designer as design recommendations to achieve better results within a specific context and with some benefits and barriers. Table 5-1 provides an overview of the design framework forming the KMS, where the focus is on how the implementation guidelines (affordances and design features) were operationalized through a set of material properties in the KMS.

<table>
<thead>
<tr>
<th>DG</th>
<th>Affordance</th>
<th>Design features</th>
<th>Material properties in the KMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ad hoc</td>
<td>Editability</td>
<td>Project setting</td>
<td>Fitting functions and content</td>
</tr>
<tr>
<td>Design</td>
<td>Modularity</td>
<td>Gateway setting</td>
<td>Connection of heterogeneous technologies</td>
</tr>
<tr>
<td>DG1</td>
<td>Improvisation</td>
<td>Emergent behavior</td>
<td>Tagging content outside social norms</td>
</tr>
<tr>
<td></td>
<td>Tracking</td>
<td>Comprehensibility</td>
<td>Wikis, comments pane and logs</td>
</tr>
<tr>
<td></td>
<td>Persistence</td>
<td>In-situ representation</td>
<td>Information exchange with mobile apps</td>
</tr>
<tr>
<td>Second</td>
<td>Granularity</td>
<td>Assembling process</td>
<td>Handling the KMS building components</td>
</tr>
<tr>
<td>Order</td>
<td>Space for act</td>
<td>Configuration space</td>
<td>Cloud-based services</td>
</tr>
<tr>
<td>Design</td>
<td>Openness</td>
<td>Projective design</td>
<td>Modular architecture to fit heterogeneity</td>
</tr>
<tr>
<td>DG2</td>
<td>Interoperability</td>
<td>Cooperative design</td>
<td>Add-ons and integration</td>
</tr>
<tr>
<td>Meta-</td>
<td>Visibility</td>
<td>Discoverable design</td>
<td>Visualizing ecosystems, tagging with context</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Customization</td>
<td>Customizable views</td>
<td>Selecting different knowledge views</td>
</tr>
<tr>
<td>DG3</td>
<td>Filtering</td>
<td>Zooming in practices</td>
<td>Filtering information to be visualized</td>
</tr>
</tbody>
</table>

The KMS is a meta-coordinated artifact composed of three independent and already existing technologies (OSF, KUMU and WallaMe) that were selected and assembled according to the requirements of the application domain. The KMS is a cloud-based system that embodies a composite of services orchestrated to support heritage experts in knowledge sharing activities. As work scenarios change constantly, the three KMS components can be combined, used in pairs or individually by having a modular architecture. Whatever the sequence of technologies being orchestrated, the KMS allow to integrate different technologies by using add-ons that expands the system capability to offer available knowledge to expert and non-expert users.

Visualizing ecosystems and tags with contextual dimensions complement the traditional way of visualizing resources in a KMS. In our prototype, every element is visualized with its inherent information but also with details about their context of use, enriching the process of discovering knowledge. In addition, the KMS offer different knowledge views that can be customizable according to user backgrounds, interest, expertise.
5.5.4 Checking validity of the sociomaterial design process

One of the most recognizable and successful models used to predict the acceptance of the information systems by users in organizations is the Technology Acceptance Model (TAM) developed by Davis (Davis, 1989) and extended by Venkatesh (Venkatesh & Bala, 2008). According to Davis, et al. (1989), the purpose of TAM is to show and explain the significant aspects that lead a group of people to use a technological tool. The core of TAM is that Perceived Usefulness and Perceived Ease of Use are decisive and correlated with the use of a system. Perceived usefulness is defined as “the extent to which a person believes that using an IT will enhance his or her job performance”, and perceived ease of use is defined as “the degree to which a person believes that using an IT will be free of effort” (Venkatesh & Bala, 2008).

Davis also theorizes that the effect of external variables (e.g., design characteristics) on behavioral intention will be mediated by perceived usefulness and perceived ease of use (Davis, 1989). This model has been revised recently to include additional factors that precede or influence this initial perception, including experience, voluntariness, subjective norms, facilitating conditions, image, job relevance, output quality and result demonstrability (Legris, Ingham, & Collerette, 2003) and has moved through various iterations pointing towards a unified model (Venkatesh & Bala, 2008; Venkatesh, Morris, Davis, & Davis, 2003). The TAM model has been used to evaluate acceptance of KMS (Hsu & Lin, 2008; Money & Turner, 2004; Yi & Hwang, 2003).

We based our measurement model in the TAM3 statements (Venkatesh & Bala, 2008) and selected result demonstrability and computer playfulness as external variables influencing perceived usefulness and perceived ease of use. Result demonstrability is “the degree to which an individual believes that the results of using a system are tangible, observable, and communicable” (Venkatesh & Bala, 2008), and so it enacts a knowledge sharing aspect of the system itself. Computer playfulness is “the degree of cognitive spontaneity in microcomputer interactions” (Venkatesh & Bala, 2008) and it represents the intrinsic motivation associated with ad hoc design of the new system. Figure 5-24 visually represents the TAM used to determine the extent to which the KMS is adopted by users. We used TAM to evaluate user attitudes towards adopting the KMS designed from sociomateriality. The methodology is supported by the hypotheses presented in the Table 5-2:

![Figure 5-24 TAM (Venkatesh & Bala, 2008)](image-url)
**Table 5-2 Hypothesis supported by the TAM (Venkatesh & Bala, 2008)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Perceived usefulness will have a positive relationship to behavioral intention</td>
</tr>
<tr>
<td>H2</td>
<td>Perceived ease-of-use will have a strong indirect positive relationship to behavioral intention</td>
</tr>
<tr>
<td>H3</td>
<td>Perceived ease-of-use will have a less strong direct positive relationship to behavioral intention</td>
</tr>
<tr>
<td>H4</td>
<td>Behavioral intention will have a strong positive relationship to system usage</td>
</tr>
<tr>
<td>H5</td>
<td>Perceived usefulness and perceived ease-of-use will have a strong positive relationship to behavioral intention</td>
</tr>
<tr>
<td>H6</td>
<td>Perceived usefulness and perceived ease-of-use will have a strong positive relationship to actual usage</td>
</tr>
<tr>
<td>H7</td>
<td>Result demonstrability will have a positive effect on the perceived usefulness</td>
</tr>
<tr>
<td>H8</td>
<td>Computer playfulness will have a positive effect on the perceived ease-of-use</td>
</tr>
</tbody>
</table>

**Instrument for Validating the KMS prototype**

The constructs and statements defined to test the hypotheses and validate the KMS using Venkatesh’s TAM methodology are presented in the Table 5-3.

---

**Table 5-3 TAM constructs, adapted from (Venkatesh & Bala, 2008)**

<table>
<thead>
<tr>
<th>Construct</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Perceived Usefulness</strong></td>
</tr>
<tr>
<td></td>
<td>PU1</td>
</tr>
<tr>
<td></td>
<td>PU2</td>
</tr>
<tr>
<td></td>
<td>PU3</td>
</tr>
<tr>
<td></td>
<td>PU4</td>
</tr>
<tr>
<td></td>
<td><strong>Perceived Ease of Use</strong></td>
</tr>
<tr>
<td></td>
<td>PEU1</td>
</tr>
<tr>
<td></td>
<td>PEU2</td>
</tr>
<tr>
<td></td>
<td>PEU3</td>
</tr>
<tr>
<td></td>
<td>PEU4</td>
</tr>
<tr>
<td></td>
<td>PEU5</td>
</tr>
<tr>
<td></td>
<td>PEU6</td>
</tr>
<tr>
<td></td>
<td><strong>Computer playfulness</strong></td>
</tr>
<tr>
<td></td>
<td>CP1</td>
</tr>
<tr>
<td></td>
<td>CP2</td>
</tr>
<tr>
<td></td>
<td>CP3</td>
</tr>
<tr>
<td></td>
<td>CP4</td>
</tr>
<tr>
<td></td>
<td><strong>Result demonstrability</strong></td>
</tr>
<tr>
<td></td>
<td>D1</td>
</tr>
<tr>
<td></td>
<td>D2</td>
</tr>
<tr>
<td></td>
<td>D3</td>
</tr>
<tr>
<td></td>
<td>D4</td>
</tr>
<tr>
<td></td>
<td><strong>Behavioral Intention</strong></td>
</tr>
<tr>
<td></td>
<td>BI1</td>
</tr>
<tr>
<td></td>
<td>BI2</td>
</tr>
<tr>
<td></td>
<td>BI3</td>
</tr>
<tr>
<td></td>
<td>BI4</td>
</tr>
<tr>
<td></td>
<td><strong>Use</strong></td>
</tr>
<tr>
<td></td>
<td>U1</td>
</tr>
<tr>
<td></td>
<td>U2</td>
</tr>
</tbody>
</table>
Each TAM construct in Table 5-3 was assessed through a set of statements that each user had to answer according to the Likert scale: strongly disagree (SD), disagree (D), neither agree nor disagree (N), agree (A) and strongly agree (SA). Taking into account that the Likert scale is ordinal, it cannot be assumed that the interval between two elements of the scale is equal to the others (Jamieson, 2004) so that in this study we analyzed the data based on the median and interquartile range parameters in order to obtain a more appropriate indication of central tendency and response variability (Anderson, Sweeney, & Williams, 2008).

The validation of the KMS was also used to verify that the prototype was sufficient to improve coordination for sharing knowledge through fitting specific requirements in the application domain. The constructs are shown in the Table 5-4.

Table 5-4 Constructs to verify fitting of specific requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge access</td>
<td>The KMS supports access to different knowledge views and findings of the projects during their different stages</td>
</tr>
<tr>
<td>Centralization</td>
<td>The KMS allow to reuse knowledge from prior projects</td>
</tr>
<tr>
<td>Knowledge retrieval</td>
<td>The KMS enable completeness of the information required to perform project activities</td>
</tr>
<tr>
<td>People access</td>
<td>The KMS afford access to people and expertise about projects</td>
</tr>
<tr>
<td>Controlled access</td>
<td>The KMS facilitate the creation and exploitation of knowledge networks</td>
</tr>
<tr>
<td>Flexibility</td>
<td>The KMS offer controlled access to project information</td>
</tr>
<tr>
<td>Knowledge visualization</td>
<td>The KMS enable visualization of available knowledge about heritage projects</td>
</tr>
<tr>
<td>Decision making</td>
<td>The KMS help expert and non-expert people in making informed decisions</td>
</tr>
</tbody>
</table>

The TAM statements shown in Table 5-4, were also measured with the aforementioned Likert scales (strongly disagree, disagree, neither agree nor disagree, agree and strongly agree).

- **Data collection**

  The respondents consisted of 42 users with different levels of expertise in both the heritage domain and technology design who were divided into four groups and surveyed in four different meetings. The first group was composed by 5 undergraduate students of architecture who were developing the last part of their undergraduate dissertation over heritage projects. The second group involved 13 undergraduate students introduced recently in the first seminar of heritage (first of three courses of the specialization area) who were developing the first part of their research project. The overall students make part of the Pontifical Xaverian University at Bogotá.
The third group was composed by 9 heritage experts working in a company specialized in developing consultancy and restoration of heritage projects in Colombia named GEA Arquitectura (https://gearqui.com). Finally, a set of 15 experts in technology design and management from different companies were invited to participate in the survey. The Table 5-5 shows the demographics of the respondents and Figure 5-25 shows GEA experts during the validation process.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Frequency</th>
<th>Valid percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>69</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>31</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-29</td>
<td>28</td>
<td>66,6</td>
</tr>
<tr>
<td>30-39</td>
<td>7</td>
<td>16,6</td>
</tr>
<tr>
<td>40-49</td>
<td>7</td>
<td>16,6</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>18</td>
<td>42,8</td>
</tr>
<tr>
<td>Graduate</td>
<td>19</td>
<td>45,2</td>
</tr>
<tr>
<td>Master</td>
<td>4</td>
<td>9,5</td>
</tr>
<tr>
<td>PhD</td>
<td>1</td>
<td>2,4</td>
</tr>
<tr>
<td>Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-9</td>
<td>31</td>
<td>73,8</td>
</tr>
<tr>
<td>10-19</td>
<td>8</td>
<td>19,0</td>
</tr>
<tr>
<td>20-29</td>
<td>3</td>
<td>7,1</td>
</tr>
</tbody>
</table>

- **Method**

Each validation session was four hours long divided into different and sequential activities, as we show in Table 5-6. During the introduction, the research team explain the purpose of the study and offered some background about the research project. Then, the participants attended a presentation of the KMS specifications including each building components as well as the most
relevant functions. In addition, a presentation was carried out by using a demo with real information of four heritage projects previously input into the system by two heritage experts. The demo was a key to capture participant’s attention and motivate them in sparking feedback during the debriefing. Afterwards, the attendees interact directly with the KMS components via a personal or group project that they were currently developing. Students used information about their graduate dissertations, heritage experts upload information about to projects performed by the company and technology experts use the system with individual projects. Finally, each group filled the TAM survey and then a debriefing session started to spark final feedback and experiential behavior with the system and the session.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>20</td>
</tr>
<tr>
<td>Presentation of KMS specifications</td>
<td>30</td>
</tr>
<tr>
<td>Setting the KMS</td>
<td>60</td>
</tr>
<tr>
<td>Coffee break</td>
<td>10</td>
</tr>
<tr>
<td>Experimental use of the KMS with a real project</td>
<td>60</td>
</tr>
<tr>
<td>TAM survey</td>
<td>30</td>
</tr>
<tr>
<td>Debriefing session</td>
<td>30</td>
</tr>
</tbody>
</table>

- **Results**

The acceptance level outcomes of the KMS prototype are shown in the Table 5-7. The table includes the count for each category, the median and the IQR. In addition, the table provides the proportion of positive responses (either A and SA in the scale) for each statement. This establishes the percentage of responders that scored the statement with either agreement or strong agreement.

The majority of the attendees agreed on the perceived usefulness of the KMS. The high value for the median parameter (M >= 4) and the average acceptance rate of 85% indicate that the attendees agreed that the KMS is useful in coordination activities for sharing knowledge. In this construct, PU4 was the item most accepted with 88% which is associated with the advantages afforded by the KMS to achieve a high level of usefulness. In addition, the other three statements (PU1 to PU3) were value with 83% each one, and so the attendees considered that the KMS supports expert in improving performance, increasing productivity and enhancing effectiveness in their job. The overall percentage of acceptance for the perceived usefulness construct was of 85% and so experts considered that the KMS is relevant and useful for their project activities.

Some attendees either disagreed or were neutral about the perceived ease of use of the KMS. The outcomes for PEU1, PEU3, PEU5 and PEU6 with less than 64% of acceptance, revealed some level of disagreement in the KMS usability, specifically about learning, mastering, facilitating, and understanding the system. However, the statements PEU2 and PEU4 were valued with a 90% and 79% of acceptance respectively and so attendees considered that they can share and find easily information needed for a project via the KMS. The overall percentage of acceptance for the perceived ease of use construct was of 69% and so a further version of the KMS could be improved in this matter.
<table>
<thead>
<tr>
<th>Construct</th>
<th>Statement</th>
<th>Frequency</th>
<th>M</th>
<th>IQ</th>
<th>% (A+ SA)</th>
<th>% Construct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Usefulness</td>
<td>PU1 Using the KMS improves my performance in my job</td>
<td>0 0 7 26 9 4 0</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PU2 Using the KMS in my job increases my productivity</td>
<td>0 1 6 22 13 4 1</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PU3 Using the KMS enhances my effectiveness in my job</td>
<td>0 0 7 22 13 4 1</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PU4 I find the KMS to be useful in my job</td>
<td>0 0 5 15 22 5 1</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Ease of Use</td>
<td>PEU1 Learning to use the KMS would be easy for me</td>
<td>0 5 10 23 4 4 1</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEU2 I find it easy to share knowledge via the KMS</td>
<td>0 1 3 18 20 4 1</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEU3 It would be easy for me to become skillful at using the KMS</td>
<td>0 2 14 15 11 4 2</td>
<td>62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEU4 It would be easy for me to find the information I need in my job</td>
<td>0 0 9 18 15 4 1</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEU5 Sharing knowledge with the KMS does not require a lot of my mental effort</td>
<td>3 7 8 15 9 4 1.3</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEU6 My interaction with the KMS is clear and understandable</td>
<td>0 3 14 18 7 4 1</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer playfulness</td>
<td>CP1 ... spontaneous</td>
<td>0 0 5 18 19 4 1</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CP2 ... creative</td>
<td>0 0 9 20 13 4 1</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CP3 ... playful</td>
<td>0 0 14 15 13 4 2</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CP4 ... motivated</td>
<td>0 2 9 20 11 4 2</td>
<td>74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result demonstrability</td>
<td>D1 I have no difficulty telling others about the results of using the KMS</td>
<td>0 2 3 18 19 4 1</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D2 I believe I could communicate to others the consequences of using the KMS</td>
<td>0 0 6 18 18 4 1</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D3 The results of using the KMS are apparent to me</td>
<td>0 2 8 21 11 4 1.3</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D4 I would have difficulty explaining why using the KMS may or may not be beneficial</td>
<td>1 1 3 9 14 5 3 2</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioral Intention</td>
<td>B1 Assuming I had access to the KMS, I intend to use it</td>
<td>0 0 6 24 12 4 1</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2 Given that I had access to the KMS, I predict that I would use it</td>
<td>0 4 13 18 7 4 1</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3 I plan to use the KMS as it becomes available</td>
<td>0 1 5 25 11 4 1</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B4 I'll recommend to use the KMS to my colleagues</td>
<td>0 1 6 25 10 4 0.3</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>U1 On average, how many times do you spend on the KMS each week?</td>
<td>3.4 days/week</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U2 On average, how much time do you spend on the KMS each day?</td>
<td>3 hours/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Computer playfulness was found to have a high median (=4) and an acceptance level above 77% indicating that one of the reasons for using the KMS is determined by the user’s motivation to use the system as it is a new technology focused specifically in the heritage domain. The results also indicate that the acceptance level is greater (>74%) for variables associated with spontaneity, creativity and motivation and so people can be motivated when they are using the system for the first time. However, a level of disagreement was found in CP3 which is related with involvement and satisfaction when using the system.

Regarding result demonstrability construct, the overall percentage of acceptance was 74% with
a median of 4, except in D4 which shows a more distributed frequency between disagree and strongly agree with an acceptance level of 45%. D4 shows that experts do not find it difficult to explain the material properties of the KMS and explain its benefits. In contrast with the acceptance level of the perceived ease of use statements with low score, it seems that once the experts master the system, they would not have any problem to communicate advantages, consequences and results of using the system in practice as the acceptance of D1 to D3 shows. The overall percentage of acceptance for the result demonstrability construct was of 74% and so the majority of the attendees believe that the results of using the KMS are tangible, observable, and communicable.

Concerning behavioral intention, 79% of the attendees would try to use the KMS if they had access to it. BI1, BI3 and BI4, with a percentage of acceptance above of 83%, show that experts would intend to use the KMS if they had access to it, however prediction of usage show a acceptance of 60%. On average, the respondents are planning to use KMS during 3.4 days per week and 3 hours each day. As a conclusion, the average acceptance level of the KMS prototype is 76%, which indicates that approximately 8 out of 10 experts are willing to use the system to share knowledge between heritage projects.

Table 5-8 Verification results of specific requirements accomplishment

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Statement</th>
<th>Frequency</th>
<th>M</th>
<th>% (A+SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge access</td>
<td>The KMS supports access to different knowledge views and findings of the projects during their different stages</td>
<td>0 0 3 16 23 5</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The KMS allow to reuse knowledge from prior projects</td>
<td>0 0 1 14 27 5</td>
<td>98%</td>
<td></td>
</tr>
<tr>
<td>Centralization</td>
<td>The KMS allow to centralize knowledge located in different personal ecosystems</td>
<td>0 0 3 12 27 5</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td>Knowledge retrieval</td>
<td>The KMS enable completeness of the information required to perform project activities</td>
<td>0 0 7 17 18 4</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>People access</td>
<td>The KMS afford access to people and expertise about projects</td>
<td>0 0 3 9 30 5</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The KMS facilitate the creation and exploitation of knowledge networks</td>
<td>0 1 2 11 28 5</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td>Controlled access</td>
<td>The KMS offer controlled access to project information</td>
<td>0 0 7 13 22 5</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>The KMS enable to set the system functionalities to fit particular needs of each project</td>
<td>0 0 1 22 19 4</td>
<td>98%</td>
<td></td>
</tr>
<tr>
<td>Knowledge visualization</td>
<td>The KMS enable visualization of available knowledge about heritage projects</td>
<td>0 0 5 16 21 4.5</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The KMS enable visualization of relations between knowledge sharing ecosystems</td>
<td>0 1 2 21 18 4</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td>Decision making</td>
<td>The KMS help expert and non-expert people in making informed decisions</td>
<td>0 1 7 19 15 4</td>
<td>81%</td>
<td></td>
</tr>
</tbody>
</table>
According to the model (Figure 5-24) and its supported hypotheses (Table 5-2), the results obtained of the TAM provide strong evidence that the KMS efficiently improve coordination for knowledge sharing by generating behavioral intention of use, despite low scores in responses to the constructs about perceived ease of use.

Results of the verification process for specific requirements are presented in Table 5-8. As revealed by the high percentage of 4 and 5 answers, signifying “agree” and “strongly agree” respectively, experts manifested their support for the KMS as a mechanism to fit specific requirements for coordination in knowledge sharing activities in the heritage domain. Moreover, the median above 4 in all constructs further supports the fact that a minimal percentage of the experts disagreed; in other words, the unambiguous consensus was that the KMS prototype supports each requirement.

- **Debriefing sessions**

In order to gather attendees’ opinions and thoughts regarding perceived usefulness and ease of use of the KMS, we also conducted a debriefing session with each group. Debriefing is the means by which attendees, who have been participated in the survey meeting as part of a validation study for the KMS, express their thoughts about both the KMS and session. The purpose of debriefing is to afford attendees with an opportunity to reflect on their experience with the KMS prototype, offer behavioral feedback and expose their observations about the KMS and the validation session (Fanning & Gaba, 2007). Face-to-Face debriefings improve the quality of information exchanged from both experts and researchers by checking data accuracy and involving an interpretation beyond the researcher and attendees, adding validity to an account (Creswell, 2013). Once each survey meeting was accomplished, the facilitator made three progressive questions that let the attendees reflect what happened, giving important insights with the aim of improving the KMS prototype towards the future. Participants were asked to freely answer the following questions:

- **What considerations do you have about the KMS usefulness to develop routine activities of heritage projects?**

Students mentioned that the KMS seems very useful to share knowledge about academic projects because current KS strategies do no support them in finding details and contacting researchers to get more information. In addition, experts from the company said the KMS affords them with possibilities to manage information in the field, where information is distributed in many sources. Finally, technology experts declared that infographic visualization is useful for project managers who do not have enough time to seek information but a short overview of the project in order to make decisions quickly.

- **What kind of things do you find positive, negative, or having potential in the KMS to support knowledge sharing?**

As positive aspects of the KMS, students said that the KMS enables collaboration as knowledge is open to others who explore it and speeds up the sharing process that usually takes a lot of time. Additionally, all groups highlighted that as the meta-coordination approach is new for them, perhaps the most significant hurdle to effectively use the KMS is culture. They considered that
shaping culture is central to facilitate the KMS appropriation, because even though the KMS allows personal ecosystems, they are connected in novel ways which require some training before starting to use it in a real context. Experts from the company considered that connecting the personal ecosystems via the KMS can spare them from separately registering in other systems, or duplicating information in different cloud-services such as Dropbox or Google Drive or sending emails to everyone involved in a project task, which they consider as a rudimentary way to share knowledge and difficult to manage as well. In addition, all groups indicated that the KMS could be adjusted to non-academic and research projects by integrating a project management service with a dashboard or a task management tool that supports team projects in planning, scheduling and controlling task flows. Finally, the groups of experts in technology declared that even though the system was designed and built for heritage projects, it seems it could be used in other domains with minor changes, which is a further step towards generalizability.

• To what extent the KMS can encourage performance improvements when developing heritage projects?

All groups agreed that with the KMS they could improve their knowledge management which is usually supported in dyadic exchanges and disperse information sources, and where relevant technical details remain hidden because of idiosyncrasy but also due to technological constraints. They also highlighted that collaborative work can be potentially improved by having centralized all the project information available and making it accessible for everyone. Finally, they remarked that the KMS can booster the “democratization of knowledge” of heritage objects.

5.6 Summary

In this chapter, we followed our reference architecture to design and build a KMS prototype in the context of heritage projects, answering the fourth research question. Specific requirements gathered from the case study of the RedPHI, literature about IS design concepts, and our reference architecture guided the construction of the KMS. As there is a lack of modelling techniques for both sociomaterial design processes and design artifacts built from it, we purposed and used the CMMN language as a way of modelling. The KMS was designed and built by coordinating existing technologies that partially meet specific requirements but jointly offers the proper material properties to support coordination in knowledge sharing activities between heritage projects. Selected technologies were integrated by using a middleware interface and in-built material properties that afford interoperability and connectivity. Several affordances and design features were embedded in the KMS, providing a great potential for coordination design and demonstrating feasibility of each design guideline. As a meta coordinated system, the individual components or a combination of them afford heritage experts with a large portfolio of coordination design alternatives that meet each specific requirement.

Different evaluations were performed to test the reliability of the KMS. The models were verified in order to ensure that the KMS prototype is properly represented. In addition, we verified that the material properties built in the KMS enact a complete, consistent and unambiguous specification of each implementation guideline. Afterwards, we applied TAM to different groups of heritage experts in order to predict the acceptance of the KMS in real settings. Finally, we
conducted some debriefing sessions to gather insights from the evaluation attendees about their experience with the KMS prototype and thoughts about the validation session. Based on the overall evaluation results, we are able to argue that the design process for KMS is improved by using our reference architecture as a design framework. Additionally, the KMS prototype designed by following our sociomaterial design process, provides heritage experts and non-experts with enough flexibility and ad hoc coordination design alternatives to improve coordination in sharing knowledge activities between heritage projects.
6 EPILOGUE

Interorganizational and multidisciplinary knowledge networks like RedPHI now aim to have more flexible and ad hoc coordination processes, in which knowledge sharing between projects must be ensured. A major hurdle for coordination in sharing knowledge is the lack of design guidance for developing KMS from a sociomaterial approach. The need for new IS design principles finds relevance in the context of heritage projects. In Chapter 4, we described a reference architecture for KMS that improves coordination in the context of knowledge sharing between such projects at an inter-organizational level. We formulated the elements of the reference architecture as design guidelines, implementation guidelines, and process structure and components to guide designers in KMS design from a sociomaterial perspective. The implementation guidelines include affordances and design features that offer empirical and operational guidance to build a KMS using a sociomaterial approach. The process structure and components are the artifact blueprint about the components of the architecture. In addition, the points of variation in the KMS design are represented via changes in contextual dimensions. These points allow designers to provide alternative instantiations of the reference architecture.

The research findings from the literature review and the case study were used to construct the reference architecture. The technical factors that influence flexible and ad hoc coordination design are involved and combined in the process structure and components. The reference architecture combines theoretical positions and empirical insights about coordination, knowledge sharing and sociomateriality. Coordination activities are considered as a core part as they are visible at all levels in the KMS including design and use at the operational level. This chapter reflects on the research findings, their contributions to the information systems field and limitations, and provides recommendations for further research.

6.1 Findings

The central research objective of this research was to develop a reference architecture for designing KMS that improve coordination activities for sharing knowledge in the cultural heritage domain. In order to develop such an environment, we formulated several key research questions in chapter one. Below we discuss the answers to the research questions.

The first research question (RQ1) was formulated as: “What are the current issues of the coordination process for sharing knowledge”. This research question was answered in Chapter 1, and further elaborated in Chapter 2. This question was intended to help us get a detailed understanding of the problems, issues, and challenges of coordination in knowledge sharing networks. The first step to answer this question was to reach a deeper understanding of our kernel theories of coordination and knowledge sharing. In addition, we asked how coordination theory had been studied empirically in the knowledge-sharing context. Chapter 2 shows that there are many scientific publications researching coordination in knowledge sharing networks, and the main barriers are the following:

- The traditional knowledge sharing models often focus only on one aspect of KM whether ICT capabilities or human activities. The preponderant view of knowledge establishes a dichotomy between tacit and explicit knowledge. Tacit knowledge is often linked with
human agency and the explicit one is related with material agency. By thinking about them as independent and separate sides, IS scholars will continue trying to explain reasons why most of KM initiatives fail, and blaming it on both infrastructure and behavioral aspects.

- IS designers see coordination mechanisms as causing some effects in the knowledge sharing process or directly in organizational performance. These deterministic perspectives suppose that coordination mechanisms are an exogenous force that can be inserted in a knowledge sharing activity or replaced without any contextual effects.

- Knowledge sharing models have been developed assuming that people, process, technology, and organizations should be integrated; however, scholars still consider that coordination mechanisms and humans are essentially different and separate realities. Some knowledge sharing studies holds an integrated view of social and material agencies by following socio-technical approaches, in which the two actors are equally important but scholars treat both agencies as independent variables temporarily aligned to perform a particular task and then separated.

- Early coordination design theory based on the information-processing view, shares the assumption that it is possible to predict what sort of coordination mechanisms people should use to manage a specific interdependency. To do so, it is necessary to identify the uncountable amount of possibilities for matching tools with knowledge needs.

- Heterogeneity in knowledge sharing activities and coordination decisions, make coordination difficult to convert coordination practices into patterns as inputs for predictive models so that IS designers should shift the design perspective from a static view of coordination to dynamic and ad hoc coordination design capabilities.

A case study was presented in Chapter 3 as the instrument to gain understanding of coordination activities for sharing knowledge. The case was useful for studying how coordination activities take place in a real application domain, identifying what kind of barriers should be overcome to improve knowledge sharing performance and exploring the limitations of the IP-view in accounting for emergent, dynamic and flexible coordination. This required a detailed understanding of the coordination processes; at the same time, a long period of observation, as coordination is continuously changing.

The second research question (RQ2) is about “what organizational and technical factors influence the design of ICT-based coordination mechanisms for knowledge sharing activities between heritage projects”. Knowledge sharing activities in RedPHI rest on a variety of ICT-based coordination mechanisms, which are employed according to contextual and situated tasks. The RedPHI network showed that coordination activities are widely variable and do not follow a predefined structure as coordination theory based on a simplistic IP-view assumes. The case study showed heritage experts’ experience of changing contexts and switching mechanisms to fit new knowledge requirements. Designing and managing coordination for sharing knowledge between heritage projects is a complex and challenging activity for heritage experts.

Based on coordination theory as kernel theory of this research, a set of interdependencies and coordination mechanisms were identified with an inductive perspective and following the IP-view. Additionally, we identified a set of coordination issues affecting knowledge sharing
performance in the RedPHI network. Those issues are not associated to the mechanisms per se, but with the situated and contextualized selection of coordination technologies within a personal and group artifact ecosystem. Accordingly, the relationship between people and technology determines the coordination characteristics for sharing knowledge. The case study findings revealed that coordination could be understood in alternative ways to match mechanisms with interdependencies, focusing on how people design and use ICT tools in ongoing coordination practices, and how these practices can alter the knowledge sharing process in interorganizational and multidisciplinary projects.

We found barriers for sharing knowledge between heritage projects are mainly due to an understanding of knowledge as a separate entity from heritage experts but also an attempt at standardizing coordination practices despite every expert coordinating their own personal artifact ecosystem in an ad hoc and contextualized manner. Barriers were related to access both to knowledge and expertise, centralization due to unsystematic disposition of knowledge, problems for knowledge retrieval from personal ecosystems, controlled access to information, standardization of knowledge, difficulties in customizing visualizations and making decisions. All of these barriers configured the specific requirements that led to a KMS prototype.

Equipped with the knowledge gained from theory and practice, we entered the design cycle of our research to answer the **third research question (RQ3)**. We formulate the reference architecture with design guidelines, implementation guidelines, and process structure and components. The research findings from background and case study were used to construct the reference architecture. The research question we addressed in this cycle concerns “how can we synthesize a reference architecture for designing KMS that supports knowledge sharing activities between heritage projects”.

The reference architecture enacts the sociomaterial design process that orients the design of an entire family of domain-specific KMS improving coordination in knowledge sharing activities. Design requirements were abstracted from aggregation of theoretical positions in our kernel theories (coordination, knowledge sharing and sociomateriality) and domain insights from RedPHI. We regard the design requirements as the specification of a particular materiality enacted by a KMS to accomplish a goal. Our design requirements are also considered as ill-defined issues as it is impossible to identify and characterize completely the dynamic and emergent aspects of coordination for knowledge sharing activities. Design requirements are related with dynamic ad contextualized connection of personal artifact ecosystems; transition between individual and collaborative workflows; support of changes in routines and technologies; and customized visualization for discovering knowledge. We summarized our design requirements in Section 4.3.

Thereafter, we formulated four design guidelines (Section 4.4) based on the design requirements. The design guidelines capture the knowledge gained about the process of building artifacts (technology-based coordination mechanisms) following the sociomaterial approach, and encompass knowledge about creating other instances of KMS that respond to the same class of coordination issues. Those guidelines are novel as they are the theoretical and empirical pillars to design coordination from a sociomaterial lens and are distinguishable from general design
principles. Ad hoc design concerns supporting dynamic and flexible design of coordination of sociomaterial ecosystems, meeting contextual changes and perceptions of affordances and constraints from coordination mechanisms being used during coordination activities for sharing knowledge. Regarding second-order design, we intended to build on the meta-coordination concept as the KMS aims to coordinate existing coordination mechanisms within and across personal artifact ecosystems, but also our design process led us to design and develop a KMS by coordinating available technologies. The logic for sociomaterial elicitation of design guidelines does not distinguish between user, system and domain requirements as traditional software engineering approaches, but rather it is based on a relational ontology in which designers discover requirements through deeper exploration of emergent and temporal conversations within and across ecosystems in which knowledge is embedded. Finally, metaknowledge implies making visible the knowledge embedded in the personal and group artifact ecosystem in a timely and comprehensible manner.

To facilitate the adoption of the reference architecture, implementation guidelines (Section 4.4) are provided. Implementation guidelines concern how IS designers can implement the sociomaterial design process for KMS at an operational and empirical level as the design guidelines were conceived as high-level abstractions. Each implementation guideline provides instructions about what affordances and design features should be designed in a KMS in order to adopt our reference architecture. Materiality built on the KMS through the implementation guidelines, provides a potential for many KMS design and use possibilities.

Based on the design and implementation guidelines, the process structure and components (Section 4.6) were introduced to show the interrelations between design guidelines and their corresponding affordances. Design guidelines lead us to consider two moments when designing a KMS: design-prior-to-use, related to activities developed by designers to design and build the KMS before using it, and design-in-use that enacts functionalities to be used by domain experts for dynamic configuration of the KMS in practice. Moving across this moments rests on the perception of affordances supporting flexibility and emergence and the actions to design, build, configure and reconfigure the KMS. Because the sociomaterial design process for KMS do not enact a standardized process, the boundaries between design moments, affordances and actions are blurred. Therefore, we consider that the sociomaterial design process allows us to carry out an ongoing KMS fit and a proper monitoring of knowledge needs to design new coordination settings.

The fourth research question (RQ4) concerns the benefit or effectiveness of using the proposed reference architecture. It was formulated as “to what extent coordination issues are overcome by using a KMS designed via the reference architecture”. The reference architecture was evaluated by triangulating expert review, prototyping, TAM and debriefing. Expert review was the primary evaluation and focused on various aspects of the reference architecture including design requirements and design and implementation guidelines. The basis of the review team for the reference architecture was independent experts from RedPHI and for the KMS prototype were RedPHI experts jointly with heritage experts from GEA Arquitectura, different experts in technology design and management and a group of undergraduate students of architecture at Pontifical Xaverian University. The overall evaluation moments (sections 3.9, 4.7 and 5.5)
evaluated the utility and generality of the reference architecture. The architecture also was evaluated by its technical feasibility to be instantiated in a KMS prototype.

The information collected from the different moments of evaluation and validation allow us to provide sufficient evidence for claiming that the design process for KMS is improved by using our reference architecture as a design framework and sociomateriality as a design philosophy. The framework can guide IS designers when designing a KMS through sociomaterial tenets, but could also lead to the design of other classes of IS. In addition, the implementation guidelines constitute a set of action-oriented principles that guide researchers and practitioners through the increasingly relevant approach of sociomaterial design and that afford them with operational and empirical knowledge that complements the widely explored philosophical principles of sociomateriality. We exhibit how KMS can be designed from a sociomaterial perspective as an instantiation of our reference architecture and how the architecture constitutes a replicable approach for designing KMS in similar contexts.

The information collected from the overall evaluations enabled us to conclude that the KMS prototype designed from our reference architecture provided heritage experts and non-experts with enough power to improve coordination in sharing knowledge between heritage projects. The findings indicated that the all evaluation participants valued the usage and usefulness of the KMS prototype positively. The affordances and design features provided in the prototype are likely to be used when they are implemented in a fully functional system. The prototype provides material properties that support dynamic, emergent, flexible and ad hoc coordination and its contribution was to fit the specific requirements identified for interorganizational and multidisciplinary knowledge sharing networks.

### 6.2 Contributions

Although sociomateriality is recognized as an alternative approach to understanding information systems in practice, it is hardly covered by theoretical investigations. Our main contribution is a reference architecture for KMS. This framework draws from sociomateriality as justificatory knowledge. The design framework was evaluated empirically by designing a KMS prototype and investigating its usefulness for the intended users and purpose. As a theory for designing sociomaterial artifacts and specifically KMS that help improve KS practices, our framework adds to knowledge on coordination design (Faraj & Xiao, 2006; P. A. Jarzabkowski et al., 2011; Okhuysen & Bechky, 2009). Our design process gives prescriptions for design and action, postulating how to design KMS from sociomateriality. The sociomaterial design process deliberately distinguishes coordination based on the IP-view from coordination understood by using a sociomaterial lens, which is relational and dynamic for rapidly changing KS environments. The proposed design guidelines introduce a novel process that helps IS designers and practitioners structure the design space enabled by sociomaterial thinking. The reference architecture also informs design decisions related to KMS. Thus, our design guidelines provide a foundation for instantiations (Gregor & Hevner, 2013) and it also expands the predominant technical and engineering focus of coordination research.

To the best of our knowledge, our study is the first to draw design guidelines from the theory of sociomateriality and empirical settings when investigating coordination. Acknowledging that
Sociomateriality is an ontological approach (Scott & Orlikowski, 2014) and design is a practical concern for how to build useful artefacts (A. R. Hevner et al., 2004), we postulate an integrated perspective of sociomaterial design (Leonardi, 2011). Sociomateriality and design can be considered as two elements epistemologically distinct each other and, if we draw on the inseparability perspective (Scott & Orlikowski, 2014), they seem an oxymoron (Bjørn & Østerlund, 2014). However, bringing sociomateriality and design together creates a new design approach where IS designers focus on coordinating not only artifacts but also changing coordination decisions while insisting on a specification of boundaries for the KMS. Our sociomaterial design process is in line with the imbrication metaphor (Leonardi, 2011) because each personal artifact ecosystem is individually coordinated based on affordances perspective, and then they are jointly meta-coordinated in the KMS configuration space, supporting KS activities. Therefore, as personal artefact ecosystems are open-ended systems, the sociomaterial design process incorporates certain degrees of freedom in the KMS design and use.

Finally, our research offers an alternative theoretical lens for examining the task of improving coordination in KS activities. As we discovered, KS challenges experienced by heritage experts can be attributed to the lack of coordination between their personal and dissimilar artifact ecosystems. A greater degree of coordination, however, cannot be achieved fully by simply defining rules, standards or routines; in fact, it requires underlying support in the relation between social and material agencies performed in sociomaterial practices. Providing the sociomaterial approach with design capabilities enables a range of useful coordination enhancements. The KMS enacts one outcome from sociomaterial designing for coordination in KS activities.

From a practical standpoint, our study provides a relevant output. As sociomaterial is grounded on practice settings, it is contradictory that it has, to date, very little to offer the IS designer (Cecez-Kecmanovic et al., 2014). Sociomateriality is especially difficult to apply in the design context because there is a lack of design process knowledge (Constantinides & Barrett, 2012; Contractor et al., 2011; Seeber, 2013). This research contributes to the practice of sociomaterial design. We have demonstrated a framework for designing a KMS from sociomateriality. The material properties of the KMS addresses many of the coordination issues identified in the heritage domain (Nova & Gonzalez, 2016a), as well as other factors associated with KS performance, including: people and knowledge access, centralization, completeness, visualization and decision making support.

Our sociomaterial design process shows that meta-coordination can be enacted by building the KMS from existing artifacts working independently (OSF, KUMU and WallaMe), and by supporting connection of different and diverse ecosystems as sociomaterial actors are highly heterogeneous. The challenge for sociomaterial design is to offer a KMS with minimal predetermined boundaries so that it is easily configured in order to face changing environments. It is up to the sociomaterial designer to identify relevant boundaries by thinking from the IP-view, but a better way to improve coordination is by offering a KMS flexible enough that it allows people to naturally connect and disconnect their own technologies.
Although the design framework emerged in the heritage domain, designers may leverage it for coordinating knowledge activities in other application domains by building KMS from sociomateriality. It is worth noting that incorporating sociomateriality in IS design process may increase complexity of the KMS's design. However, we believe this is more than counterbalanced by the benefits in coordination for KS in real environments. We, therefore, advocate IS designers in spending more time and energy on identifying the practical implications associated with design and coordination of new technological artifacts, recognizing co-constitution and co-evolution of non-static assemblages of people and CMs.

6.3 Research approach
In the previous section, we discussed the output of the research. In this section, we reflect back on the research methodology used. To address our four research questions proposed in Section 1.5, we used a research methodology that have three dimensions: a research philosophy, a research strategy and research instruments.

In this doctoral thesis, we considered design science as our research philosophy, since our research problem is ill-structured. The scientific contribution of this work comes through the development of a design artefact and testing its utility in improving the existing situation, thereby adding value to the practice of designing sociomaterial KMS for the heritage domain. The outputs of design science were assessed against criteria of value or utility (March & Smith, 1995). The goal of the research was to improve the design of ICT-based coordination mechanisms for knowledge sharing. We believe that the work was value-oriented, and served a human purpose (March & Smith, 1995), thereby supporting our choice of design science as an appropriate research philosophy for this work.

Our design process and design product enact the sociomaterial tenets of inseparability between social and material agencies, and so we demonstrated prior arguments about how the sociomaterial lens can complement DSRIS (Hovorka & Germonprez, 2011; Yoo, 2010) to better understand the design of sociomaterial assemblages at operational and empirical level, but this requires we acknowledge that the phenomenon we are studying is the result of the entanglement of several actors in the environment.

Based on the requirements, we were able to design our artifact. We followed the guidelines for design science (A. R. Hevner et al., 2004) in our research. The guidelines helped us to design a reference architecture (design process as artifact) and the corresponding KMS prototype (design product as artifact) by first identifying the real coordination and design issues (problem relevance), exploring theories, methods and instruments for the construction of both architecture and KMS (rigor), and then evaluating the design artifacts by triangulating expert review, prototyping, TAM and debriefing (design evaluation).
6.4 Limitations, future work and recommendations
Several limitations that emerged during our research project could be developed in future research. We discuss those limitations and link them to recommendations for further study, but additionally we offer some recommendations to do that. Limitations of the present work can be categorized into theoretical, methodological and practical scope.

6.4.1 Theoretical and methodological approach
The scope of the research is the sociomaterial design of KMS. Due to the very limited knowledge on designing IS from sociomaterial tenets, we made several decisions at different moments of the research, which could have influenced the results of it. Decision regarding the philosophical approach of the research grounded on a critical realist view of sociomateriality, leaded the development of this research, as basic theoretical fundamentals were available in a narrow but available corpus of knowledge. Having no comparison with other research project in sociomaterial design of KMS, our research is limited by the theoretical lens of Leonardi´s work. In this research, we did not address the Orlikowski´s view of sociomateriality as we considered it as properly fitted with theoretical research but not for empirical one as we posited in Section 2.5. It does not mean that the agential realist view of sociomateriality cannot offer a valuable support for designing information systems, however, we decided to advance in this matter over the knowledge already existing in IS design, rather that expanding the debate between the proper metaphor or philosophy of sociomateriality.

- Recommendation: Investigating if sociomaterial design from agential realism view is possible, and how this process should be specified to be used by IS designers in practice. Defining a set of aspect to compare our solution with the alternative ones to give better insights for analysis and design purposes.

We performed a large exploration of the RedPHI as the problem space in which reside the phenomena of coordination for sharing knowledge. This longitudinal case study allowed us to get a deepen knowledge about sociomateriality in the heritage work but also in the heritage itself. The design was evaluated in a particular domain (KS between heritage projects at the RedPHI) with specific boundary conditions and organizational characteristics; therefore, it might be argued that the design process needs to be adjusted for other type of KS settings. Indeed, the design guidelines may be applied in other domains and artefacts, allowing for further generalization of our findings – generalizability from theory to description (Lee & Baskerville, 2003). In doing so, there is a challenge for testing and confirming the applicability and accuracy of the artefact to be generalized in a new setting.

- Recommendation: Instantiating our reference architecture in other domains and test the system in other knowledge networks by using the sociomaterial design process that we developed in this dissertation. Designing other class of IS artifacts related with knowledge management such as decision support systems, knowledge based systems, groupware systems, project management tools, among others. These could lead to boost the learning about sociomaterial design in other environments and technology domains.

Considering the scarce knowledge on empirical methods for exploring sociomateriality in practice (Constantinides & Barrett, 2012), as well as our objective to design a reference architecture for KMS from sociomaterial tenets, the prescriptive design science research approach was quite
appealing. We then grounded on the DSR by Hevner et al. (2004) to study theoretical knowledge, to investigate empirical situations, to develop the design artifact, and to evaluate our findings. Even though DSR classifies as critical realism (Carlsson, 2006), it is grounded on the socio-technical paradigm (Drechsler & Hevner, 2015) and there is a lack of methodological guidance for sociomaterial exploration. Even though some scholars have recently started to explore connections between DSR and sociomateriality, the implications of sociomateriality for design science research have been little discussed (Hovorka & Germonprez, 2011; Yoo, 2010). Therefore, some of the guidelines for design science in information systems research of Hevner et al. (2004) were not able to support our sociomaterial design goal. Later, limitations have relevance with the research methodology and strategy we used. The choice of DSR as methodology to conduct our research could have influenced not only the explanations we found, but also the scope we took.

- **Recommendation:** Investigating methodological guidance of sociomateriality and its connection with DSR is highly required and could be determinant in the positioning of sociomateriality as an alternative vision of the IS design.

### 6.4.2 Practical scope

In the practical domain, the reference architecture is based on a set of four sociomaterial design guidelines, which were instantiated in a KMS for the heritage domain. As the author of this dissertation created, implemented and evaluated the architecture, it remains to be explored how other IS designers will use the design guidelines in real design practices and whether they will find them useful. These lead us to other limitation regarding skills that an IS designer should have in order to use our design guidelines. We consider that IS designers applying our reference architecture must have some basic knowledge about sociomateriality. Consequently, usefulness of this dissertation is in two-way, on the one hand, it includes fundamentals of sociomaterial IS design as applicable knowledge, but on the other hand, it offers a set of design and implementation guidelines that lead them when designing a KMS.

- **Recommendation:** conducting a meta-analysis about the design guidelines instantiation. This could help scholars and practitioners on sociomateriality to adjust or extend our reference architecture.

The large part of the case study was focused on identifying design requirements and formulating design guidelines and, at the final stage of the research, some evaluation and validation strategies were carried out (see sections 4.7 and 5.5) over the KMS prototype. We considered that the best test for the reference architecture was the instantiation in a KMS prototype but a replication test to evaluate deterministic effects of the design guidelines is then a challenge of our research. Even though the evaluation of the KMS prototype in section 5.5 indicates that the heritage experts consider that KMS efficiently improve coordination for knowledge sharing, a longitudinal evaluation of the KMS prototype performance indicating sustainability of our solution for coordination issues is still missing. Further investigation should be done to assess its usability and usefulness in large knowledge networks with a large number of actors and complex coordination and knowledge sharing processes.

- **Recommendation:** exploring replicability of the reference architecture effects in similar organizational settings by designing a KMS in a different domain. New evaluations involving real stakeholders using the KMS during a prolonged period are desired. A
monitor system could help designers or chief knowledge officers to evaluate partially advances in coordination and so re-configuring the system during the design-in-use time.

As we posited in section 5.2, current literature on sociomaterial design do not account for modeling techniques, tools, strategies and guidelines that empower designers in representing graphically or theoretically sociomaterial design activities. Modelling languages for information systems are strongly based on information processing; are focused on automation of business process; their notations are too restrictive and limit changes during process execution; and consider a separation between perception and design. However, we proposed CMMN language as a way of modelling sociomaterial design processes for KMS arguing that it comes closest to affordance and constraint theories. Event tough we use this language to model and build our KMS prototype, the use of CMMN for modelling alternative KMS or even other artifacts designed with our reference architecture, remains unproven.

- Recommendation: Adapting the CMMN language to the overall sociomaterial principles or maybe develop a specific language for sociomaterial design that completely accounts for modelling tasks. Useful guidelines to support sociomaterial modelling could address complexity in design model.

When evaluating the KMS prototype, we did not found validated measurements models for artefacts built from sociomateriality. The few papers working on sociomaterial design do not state clearly what measurement performance authors used for evaluating the artifacts and some evaluate them through use cases and critical appraisal. We used the technology acceptance model –TAM to predict the acceptance and rejection of the KMS prototype by measuring its perceived usefulness and perceived ease of use. Even though TAM foundations, the affordance theory and the imbrication metaphor have in common the perception theory in which human perceptions causes people to accept or reject a technology, there is still a lack of studies about their potential use as an overall sociomaterial measurement model and whether all the variables and items of the model can be explained from sociomaterial tenets.

- Recommendation: In order to provide solution for limitations arises from lack of sociomaterial measurement, our suggestion is to evaluate, extend or adapt the TAM, to make it familiar to and meet the sociomaterial foundations and constructs in the design arena. This means to build upon the existing knowledge about technology acceptance, however, to design a new measurement model for sociomaterial artefacts is also recommendable.
REFERENCES


8 APPENDIX

8.1 Appendix A – Network map for heritage actors at the PUJ
### 8.2 Appendix B – Interaction matrix between heritage experts

| ASIGNACIÓN  | Investigador principal | Investigador externo | Investigador experto | Asesor externo | Director del equipo de investigadores | Coordinador de recursos | Contralor financiero | Director de recursos | Director de investigación | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | Director de la entidad | 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- First number represents frequency of interaction (scale 1-5)
- Second number represents intensity of interaction (scale 1-5)
- Third number represents value of information (scale 1-5)
- Fourth number represents means of interaction (0-formal; 1-informal)
- Fifth number represents the way of interaction (0-unidirectional; 1-bidirectional)
8.3 Appendix C – Affordances perceived during heritage work
## 8.4 Appendix D – Coordination matrix

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<tr>
<th>MECANISMOS DE COORDINACIÓN (Maloney, Crooks 2002)</th>
<th>III. Diferencias metodológicas y epistemológicas</th>
<th>IV. Múltiples universidades, depósitos, grados, disciplinas</th>
<th>V. Múltiples disciplinas</th>
<th>VI. Diferencias horizontales y geográficas</th>
<th>VII. Organizaciones de diferente tipo</th>
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NOTA: ☑ = Indicador de contacto activo; ☑ = Indicador de contacto inactivo; ☑ = Indicador de contacto potencial.
8.5 Appendix E – Middleware interface
SUMMARY

Sharing knowledge about the historical and cultural heritage often requires coordination of heterogeneous agencies composing multiple, different and independent ecosystems under diverse contextual dimensions. Coordinating complex and dynamic knowledge sharing (KS) activities is hard. Several and heterogeneous experts are often involved in cross-disciplinary and temporary projects in which knowledge coordination is crucial. Heterogeneity in people, disciplines and expertise, as well as in technology, contexts, and interests, produces ontological and epistemological differences that can hinder the knowledge sharing performance (Faraj & Xiao, 2006; Okhuysen & Bechky, 2009). Moreover, coordination difficulties increase as knowledge workers use diverse and different personal artefact ecosystems for sharing knowledge (Treem & Leonardi, 2012) which they manage in discretionary, dynamic, emergent and contextual ways. Furthermore, the current and dominant coordination design perspectives leading the design of KMS do not account for the ongoing, complex and dynamic interactions between and among human and material agencies and how those relationships in practice enable or constraint the knowledge coordination.

In the last decade, scholars in the IS discipline have started to re-conceptualize relations between human and material agencies, examining how actions and relations between agencies are materially constituted in practice, and thus sociomaterial in nature (Feldman & Orlikowski, 2011; Leonardi & Treem, 2012). Even though sociomateriality has contributed to understanding the role of technology in today’s organizational practice (Leonardi, 2013) and has gained traction in the IS literature (Cecez-Kecmanovic et al., 2014), less attention has been given to the SM design of IT artefacts (Constantinides & Barrett, 2012; Contractor et al., 2011; Leonardi, 2013; Seeber, 2013). Current sociomaterial design approaches are focused on understanding sociomateriality in practice and at present there are two well-known frameworks to conduct design studies (Bjørn & Østerlund, 2014; Leonardi & Rodríguez-Lluesma, 2012), however, the scope of these streams just guide designers in eliciting requirements but not in designing IT artefacts from sociomaterial thinking. This lack of applicable sociomaterial design knowledge produces incoherent solutions for coordination issues, because coordination can already be understood from sociomateriality (Constantinides & Barrett, 2012; Nova & Gonzalez, 2016b) but, then, it is designed from a socio-technical perspective.

This problem situation leads to research questions. (1) What are the current issues of the coordination process for sharing knowledge? (2) What organizational and technical factors influence the design of ICT-based coordination mechanisms for knowledge sharing activities between heritage projects? (3) How can we synthesize a reference architecture for designing KMS that supports knowledge sharing activities between heritage projects? (4) To what extent coordination issues are overcome by using a KMS designed via the reference architecture? The research approach used to answer these questions follows a design science research strategy with three cycles: a relevance cycle (using a case study), a rigor cycle (exploring the theoretical knowledge base) and a design cycle (using prototyping). The results include an instantiated artefact and a theoretical contribution comprising constructs, methods and models.
Following the DSR approach (A. R. Hevner, 2007), we went through three iterations, each one consisting of a relevance, rigor and design cycle, in order to propose and develop the design guidelines and to demonstrate and evaluate them through a prototypical instantiation. Our research domain is the Iberoamerican Historical Heritage Network – RedPHI, which is specialized in cultural and historical heritage management (Red PHI, 2018). RedPHI is an international and interorganizational network of 46 universities of seven countries aiming to share specialized knowledge between expert and non-expert people supporting decision-making in public and private institutions, which are interested in getting involved in activities such as rehabilitation, conservation or protection of material and historical heritage.

First DSR iteration: eliciting design requirements.
By the start of the research, coordination activities for sharing knowledge at RedPHI were explored by following the information-processing (IP) view as the most common coordination perspective in the information systems discipline. Several coordination issues were identified at RedPHI, which are mainly related to the understanding and design of coordination in practice as a matter of reducing IP needs or increasing IP capabilities. This perspective rest on a socio-technical perspective, in which material agencies are separated from but determines the social agencies. By means of triangulation of several sources of evidence from RedPHI (experts’ interviews, documentation and direct observation) and the exploration of the existing corpus of knowledge about coordination, knowledge sharing and sociomateriality in the information systems literature, sociomateriality was postulated as a means to understand and enhance knowledge coordination. By using a critical realist view of sociomateriality, we used some concepts such as agencies, affordances, imbrications, conversations and trading zones, among other, in order to deepen understand coordination in practice at RedPHI. As a result, we formulated four design requirements for KMS from sociomaterial tenets, regarding interconnection of individual ecosystems; transition and combination between individual and collaborative workflows; changes in routines and technologies; and knowledge visualization. Evaluation of the requirements was conducted through three expert review sessions, in which participants highlighted that the design requirements properly enacts their current coordination needs.

Second DSR Iteration: formulating design guidelines. In the second iteration, we built the state of the art of sociomaterial design, identifying current principles and challenges in designing IT artefacts as well as artefacts already designed from sociomateriality. In doing so, we explore specific literature about connection between sociomateriality and design in the information systems discipline. Both the theoretical positions of sociomaterial design and the empirical insights gathered from RedPHI were used as conceptual basis to conduct two design workshops with heritage experts from RedPHI and technology designers from Purdue University. Workshops insights were concerned with sociomaterial design ideas for coordination materials and the materiality that the KMS should afford in real coordination practices. By joining the problem space with the solution space, a reference architecture composed by four design guidelines and their corresponding implementation guidelines was formulated. The architecture enacts design decisions for designing KMS from sociomateriality, while design guidelines represent the high-level conceptual meaning of the sociomaterial design. The implementation guidelines encompass affordances and design features as the operational and tangible landing of
the design guidelines to be applied in real design practices. The design guidelines enact the fundamentals of sociomaterial design from a critical realist view such as design in practice; perception-based design; sociomaterial exploration of imbrications; and metaknowledge. In order to evaluate the guidelines, a basic version of a KMS was designed followed by a proof of concept, which were explored and validated by a group of heritage experts. Later, the reference architecture, as the main design artifact in this research, was instantiated in a KMS prototype.

**Third DSR Iteration: building a KMS prototype.** We developed the KMS prototype, building on the conceptual framework, the design requirements, the reference architecture and the empirical research gathered from the application domain. A KMS was designed as a prototypical instantiation of the SM design guidelines. The design process involved the exploration of the knowledge base on KMS design, which in turn was extended by empirical insights gathered during the SM design and development. The KMS enacts a higher order composite service built through existing and independent fine-grained technologies, each one affording multiple and distinct possibilities for action, which were assembled as a whole single KMS, offering several affordances to improve coordination in knowledge sharing practices between heritage projects. Both, the design process and the KMS prototype, were modelled through CMMN language in which designers can determine the initial materiality of the KMS (prior to use design) and then, they can configure and reconfigure discretionally functions and content (design in use) as they perceive new affordances or constraints when using the system in practice. The utility of the KMS in coordination activities for sharing knowledge was evaluated via TAM; the satisfaction of the specific requirements was checked via survey; and the behavioural feedback and personal observations about usefulness, potentialities and performance of the KS was gathered via debriefings. Evaluation outcomes led us to refine the design guidelines and confirm the potential utility of the design artefact to reach knowledge coordination enhancements in the heritage domain.

With respect to the first research question this research found that coordination issues are mainly due to individual and non-rational preferences held by heterogeneous experts when selecting and crafting personal coordination ecosystems that at some point need to be coordinated in order to enable the knowledge work. Traditional knowledge coordination design approaches rest on the socio-technical dualism of tacit and explicit knowledge and supports the determinist perspective in which materiality determines the coordination behavior and so it is possible to design coordination in advance even though this research demonstrates that coordination is dynamic, emergent and contextualized. The matching perspective of the IP view suggest to identify dependencies and coordination mechanisms separately and then to merge them by following a static and programmed plan. However, heterogeneity in social and material agencies, relationships but mainly in affordances and constraint perceptions leads to consider coordination design as an ongoing and ad hoc practice.

The second research question asked about the social and material aspects that influence the coordination design. The case study findings revealed that coordination could be understood in alternative ways to match mechanisms with interdependencies, focusing on how people design and use ICT tools in ongoing coordination practices, and how these practices can alter the knowledge sharing process in interorganizational and multidisciplinary projects. This insight
differs from the socio-technical approach which argue that knowledge coordination is managed at organizational levels in terms of organizational culture and structure, standardization, labor division, or power relationships, but not at individual and group levels, where people design and redesign discretionally their own sociomaterial ecosystems, even having organizational rules to use a specific mechanism in a mandatory way. We also found several knowledge barriers that supports the contradictory perspective of understand coordination from sociomateriality and then, design it from a socio-technical view. Barriers are related to access and expertise access, centralization due to unsystematic disposition of knowledge, problems for knowledge retrieval from personal ecosystems, controlled access to information, standardization of knowledge, difficulties in customizing visualizations and for making decisions.

The third question asked about designing a reference architecture for KMS from the sociomaterial perspective, aiming to overcome the coordination issues for sharing knowledge between heritage projects. The reference architecture enacts the sociomaterial design process that orients the design of an entire family of domain-specific KMS improving coordination in knowledge sharing activities. The architecture involves the elicitation of four design requirements which were abstracted from aggregation of theoretical positions in our kernel theories (coordination, knowledge sharing and sociomateriality) and domain insights from RedPHI. We regard the design requirements as the specification of a particular materiality enacted by a KMS to accomplish a goal. The design guidelines are the theoretical and empirical pillars to design coordination from a sociomaterial lens and the implementation guideline provides prescriptive knowledge for chief knowledge officers or software developers when designing a KMS from sociomaterial tenets. Instantiating the design guidelines in a KMS prototype provided theoretical and empirical insights about how the sociomaterial tenets can lead the coordination design and how does it leads to improvement in coordination for sharing knowledge.

The fourth research question focused on test the effect of the sociomaterial design in coordinating knowledge sharing activities. Evidence collected at different evaluation and validation moments allow us to claim that a KMS designed with the reference architecture enacting sociomaterial design, can potentially overcome the coordination issues in the knowledge work. Participants in the evaluation highlighted that the utility of the KMS for their heritage projects is demonstrable, communicable, observable and tangible, and so they are engage with using the system during the heritage projects as a way to improve the sharing knowledge activities between heritage projects. They considered that by using the KMS in practice, it would be possible to overcome the knowledge barriers that affect the knowledge sharing process between heritage projects and limit the protection of the heritage objects. Additionally, the KMS afford possibilities to overcome cultural barriers that limits coordination for sharing knowledge. Ultimately, the KMS prototype provides material properties that support dynamic, emergent, flexible and ad hoc coordination and contributes to fit the specific requirements identified at RedPHI.
CURRICULUM VITAE

Néstor Armando Nova Arévalo was born on February 3rd 1983 in Bogotá, Colombia. Néstor obtained his degree in Control Engineering in the year 2007 from Universidad Distrital Francisco José de Caldas in Bogotá. After graduation with distinction, he worked as project leader in two companies in Colombia in energy and metrology areas. He then went on to obtain his MSc in Industrial Engineering in the year 2008, after being granted a scholarship from the Universidad Distrital Francisco José de Caldas. During his master career, he was involved with teaching in the areas of Automation, Rational Use of Energy, Statistics and Operational research in the Universidad Cooperativa de Colombia and the National Police Academy in Bogotá. His master's thesis project was about to characterize and model the regulator effect in mobile services over the economic rationality and decision-making of users through second-order cybernetics. In 2014, he took a leave from his position to carry out his PhD research in the Systems Engineering Faculty of the Pontifical Xaverian University after being funded by Colciencias in Colombia. Part of his research has been published in international conferences. During his PhD studies, he participated in a number of projects, published some papers, and advised a number of master’s thesis projects. During his doctoral research he worked as academic guest at Rocketed Research Group at Purdue University, Indiana, USA for 6 months in 2017, supporting experiments with visual and haptic technologies on students’ learning of friction concepts.