# AFFORDANCES AND AGENTIAL REALISM: A RELATIONAL ONTOLOGY FOR A RELATIONAL THEORY

*Research paper*

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## Abstract

*Relational view of affordance theory has emerged as a viable theory in Information Systems (IS) research to explain variation in IS use. According to this theory, what a specific person can achieve with a technology is neither inherent in the person himself nor on the technology but emerges from their interaction. Despite that such relational view implies relational ontology, the ontological foundations have been insufficiently theorized which limits both its practical and theoretical applicability and explanatory power. In this paper, I suggest that Karen Barad's relational ontology, known as agential realism, provides coherent and solid foundations for affordances that are especially suitable to explain IS use in contemporary workplace that is characterized by distributed yet tightly interconnected technological infrastructures rather than dyadic interactions with simple objects. Empirical illustrations drawn from ethnographic field work of technicians working with smart infrastructure show how affordances building on agential realism may enhance understanding of IS use.*


*Keywords: Affordances, Agential realism, Ontology, Theory, Sociomateriality, Infrastrcture*

# 1 Introduction

A key concern for information systems (IS) research is how and why technologies become used differently across contexts and produce different organizational outcomes (Straub & Giudice 2012; Burton-Jones & Grange, 2013). When technologies become situated as part of the mélange of human motives, practices, and tools that constitute organizational life they become differently enacted and used (Feldman & Orlikowski, 2011). The interpretive flexibility of technologies allows multiple interpretations and uses of the same technology within and across contexts (e.g., Orlikowski & Gash, 1994), and produce outcomes that are hardly foreseeable before their actual use (e.g., Zammuto et al., 2007). The difficulty in forecasting variation in technology use is not, however, merely an unwanted trait of human ingenuity but may actually engender new and innovative ways to appropriate a specific technology (e.g., Monteiro et al., 2014) Consequently, it is not sufficient to study merely how technologies are designed but to study their actual use (Straub & Gjudice, 2012).

Affordance theory has become one of the viable and popular theories in IS to explain what technologies afford for users and the outcomes they produce when used. In contrast to theories that focus purely on social or cognitive factors (such as psychological antecedents for behaviour), affordance theory seeks to bring the IT artefact to theorizing (Orlikowski & Iacono, 2001). More precisely, affordance theory positions that the materiality of technology shapes the ways in which the technologies become perceived and used.

The different ways in which the technologies can be used is not without boundaries or limits (i.e., not everything or anything is possible), but conditioned by both the perception of the user and the materiality of technology. However, neither perception nor technology can determine how the technology is used but the use is relational to how the social and the material entangle in practice. Metaphorically, it is as in the famous case study from a neurologist Oliver Sacks (1985), who reports of a man, who from his appearance seemed healthy and well, but who suffered from a rare perceptual impairment due which he took his accompanying wife to be a hat and sought to wear her at the end of a therapy session. Despite the patient's firm belief and perception that she indeed was a hat, the wife did not afford this type of use. This relational view of affordances in which the possible uses of a technology (or a material object in general) resides in the relation between user and a technology is particularly popular in IS research (Leonardi, 2011; Volkoff & Strong, 2013; Fayard & Weeks, 2014; Pozzi et al., 2014; Zammuto et al., 2007).

The relational view raises important concerns over the ontological nature and status of affordances. How should we understand the nature and existence of affordances (i.e., their ontology) if they exist in the relation, and not in the entities per se? While calls have been made to clarify the ontological foundations of affordances (Robey et al., 2012; Fayard & Weeks, 2014), the discussions have been insufficient in the sense that what has been lacking is a coherent framework that takes relations as the ontological foundations. In this paper, I argue Karen Barad's (2003; 2007) philosophical framework, known as agential realism (AR), provides plausible and appealing ontological foundations for affordances. It goes against popular thought in that it does not start from the assumption of discrete entities that are then in the need of an explanation of why and how they congregate, intermingle and come together as (seemingly) one and produce that which is emergent (cf. Volkoff & Strong, 2013; Fayard & Weeks, 2014; Leonardi, 2011), but starts from the position that there are only networks of relations and things that is the ontological nature of the world and the reality. Besides the theoretical curiosity and philosophical coherence, turning to the philosophical foundations have much practical relevance. Philosophical foundations fundamentally alter the way in which we research and experience the world, and render certain aspects in our theories and explanations more salient and visible than others (Orlikowski & Baroudi, 1991).

By drawing attention to the relational view of ontology (Emirbayer, 1997), AR broadens our view of affordances and foregrounds new aspects that have been faded into background. Central to my AR-informed arguments is that, by conceptualizing affordances as emergent, dyadic relations have gained priority over networks of relations in past studies. Focusing on dyadic relations easily overshadows the fact that we live in a (technologically) networked and interconnected world that is characterized by dynamic infrastructures (cf. Tilson et al. 2010a; 2010b) rather than interactions with (passive) objects (Monteiro et al., 2013). To this extent, my arguments are sympathetic with Bloomfield et al. (2010) in that "we need to look beyond the (individual) human / (individual) machine dyad" (p. 428). By looking beyond, I wish to draw attention to the complex sociomaterial arrangements that underpin and form the technological infrastructures our lives have become entangled with and that undergird and shape our actions. To show the practical usefulness of how the affordance theory founded on AR may improve our understanding of IS use, I will draw illustrations from on an ethnographic field work of technicians' work in a smart infrastructure setting (Constantinides et al., 2016).

Rest is structured as follows. First, I will provide a brief background on affordances in IS research. Second, I will lay out the philosophical foundations of AR and elaborate those foundations through a practical example of an Internet search engine. Third, I will provide some empirical illustrations on how affordances that build on AR may help to make sense of empirical phenomenon. Last, discussion and conclusion are provided.

## 2 Affordances and Information Systems Research

The concept "affordances" is a neologism originally brought forth by ecological psychologist Gibson (1979). According to him, "[t]he affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill." (Gibson, 1979, p. 127). As Jones (2003) has shown, Gibson's conception of affordances evolves in his oeuvre and he never finished the work during his lifetime. Nevertheless – or perhaps just because of that – Gibson's work has shown much plasticity that has made it influential across disciplines and contexts. This plasticity is, indeed, necessary when importing ideas from such distant discipline as ecological psychology to IS research. Volkoff and Strong (2013) note that when importing such theories, we need to at least recognize that "we are no longer dealing with just individual goals and actions, but also group or organizational goals, and the coordinated actions of groups of people to support them." (p. 823). "There is also a question as to whether the language of animal–environment pairings provides an adequately sociological lens for viewing encounters with technological artefacts." (Bloomfield 2010, p. 417) Despite of these difficulties, IS scholars have provided insightful studies that show the applicability of affordances to IS related phenomena at organization-, group-, and individual-level of analysis (e.g., Zammuto et al., 2007; Leonardi, 2011; Fayard & Weeks, 2014).

An important aspect of affordances is that they are concerned not of action per se but of possibilities for action (Pozzi et al., 2014). As such, affordances do not seek to define which action any person will take neither even make predictions about which is the most likely course of action but merely describes the space of possibilities within which action takes place. Understanding and uncovering the space is significant as this space may explain variation in the way certain technology becomes used as use is not strictly bounded activity but unfolds within this space of possible actions. Consequently, relational view of affordances does not assume that a technology would have merely a single use, but that the same technology may afford multiple uses. A mobile phone affords emailing, text messaging and calling to those who knows how to use a mobile phone, but those affordances are not available to an animal (or to those who do not know the phone's security code to unlock the phone!).

Volkoff and Strong (2013) note that one of the areas of debates around relational view of affordances have been its ontological basis, but that "[a]fter some debate, the consensus emerged among ecological psychologists that an affordance is a *property of the relationship*" (emphasis mine)(p. 822) More accurately, affordances are often conceived not just as a property of the relationship but a property of a relationship that is emergent (e.g., Fayard & Weeks, 2014; Volkoff & Strong, 2013; Leonardi, 2011). Volkoff and Strong's (2013) recent and influential definition illustrates this well: "we define affordances as the potential for behaviors associated with achieving an immediate concrete outcome and arising from the relation *between an object* (e.g., an IT artifact) *and* a goal-oriented *actor or actors*" (emphasis mine)(p. 823). A precondition for emergence is the existence of two (or more) separate things that have their own individual inherent properties, and that, when combined, produce properties that are not present in any of the two in isolation. Such a view builds on an ontology of discrete entities (such as critical realism (e.g., Wynn & Williams (2012); Mutch (2013)) that assumes that it is possible to make (objective) interaction-free claims about an object. In any other case we are always and already interacting with that object (whether it is with a scientific apparatus or in everyday encounter) which would imply that we only see and describe that which is emergent and not that which is the object(ive). I see this view problematic and suggest that a potentially stronger foundation can be built on relational ontology that does not presuppose existence of discrete entities neither "emergence"[1]. Building on different ontological foundations is also methodological (Cecez-Kecmanovic, 2011). It helps to shift focus and attention from dyadic interaction to networks of interactions that enables placing matter in to a more active role and designating sufficient complexity to contemporary technologies that they deserve. Central to my argument is that, we should not only recognize that when importing theories from ecological psychology that we are no longer dealing with just individuals (Volkoff & Strong, 2013), but also that we are no longer dealing with simple objects such as chairs[2]. Indeed, "[t]he universe is filled with all manner of objects, only a subset of which are technological objects" (Faulkner & Runde 2013, p. 806), but the technologies we as IS scholars study and that the subjects of our studies encounter are only rarely any isolated, technological *objects* but complex, distributed, and dynamic sociomaterial infrastructures.

# 3 Reconceptualizing Ontology of Affordances

Before outlining the affordances that build on agential realist (AR) foundations, I will introduce its main tenets briefly. The discussion is kept philosophical and generic in order to provide sufficient background on AR to reconceptualize the ontological foundations of affordances. After introducing AR, the reconceptualization of affordances is elaborated with a more specific IS related example.

## 3.1 Agential Realism

AR has broadly informed IS literature on sociomateriality (e.g., Orlikowski & Scott (2008); Scott & Orlikowski (2014); Scott & Orlikowski (2015); Mazmanian et al. (2014); Schultze (2011; Niemimaa, 2016); Jones (2014); Østerlie et al. (2012); Boell & Cecez-Kecmanovic (2012); Cecez-Kecmanovic et al. (2014)), and discussions around "new materialism" or "materialist turn" outside IS discipline (e.g., Lemke, 2014; Dolphijn & van der Tuin, 2012). AR originates from the works of physicist and naturalist philosopher Karen Barad (2003; 2007). From her naturalist philosophical stance (Rouse, 2004), the latest discoveries of sciences, especially those of the physics, should also inform philosophy (Barad, 2011). Thus, it is no wonder that she takes quantum mechanics, and especially that of Nils Bohr's physics-philosophy, as the starting point for her philosophical endeavor that she then expands beyond any disciplinary boundaries, and while doing so, questions many of the taken-for-granted assumptions, tearing down walls around disciplines and lines of thinking. The crucial argument and the most central aspect from which all other arguments follow is the reworking of ontology of discrete entities into a relational ontology. As such, her work resembles other network ontologies, especially, Actor-Network-Theory (e.g., Latour (2005)).

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[1] Strictly speaking, there can be no emergence (i.e., that the whole is more than the sum of its parts) in fully relational ontology, since there are no individual entities prior to their entanglement.

[2] See Lanamäki et al. (2015) for a collection of excerpts that show just how popular "a chair" has been in the debates and discussions around affordances.

Barad argues world is constituted not of discrete entities but of phenomena. For her, phenomena are not representations of some aspects of the world, where the actual real world would exist somewhere hidden behind or underneath our conceptual representations, but phenomena are certain configurations of the world. There is no clearly demarcated world with discrete entities awaiting for discovery 'out there' prior to our engagement with that world, but that all we know about the world and the world is always relational to the ways in which we engage with that world. As such, the concepts we use to describe the world are neither representations of the world but are also material apparatuses through which the world materializes in a certain way. This is what she means, by referring to Friedrich Nietzsche that we should not take our language too seriously as a mirror of the world. World is not organized neatly according to our descriptions of the world and the concepts, but it is us and our engagement with the concepts and the world that materializes the world in a certain way and gives the objects their boundaries and properties. What she argues then, is that "the natural world only acquires definite boundaries, and concepts only acquire definite content, together" (Rouse, 2004, p. 146). As such, what she reworks is not just ontology, but the whole ontology/epistemology relation.

Phenomena are constituted by "things" (agencies in Barad's terms) that are meaningful only within a certain phenomenon. As the "things" receive their boundaries and properties only in relation to one another, and are non-existing outside of those relations, they are not discrete entities but networks of entities. While this may sound rather radical, Barad's ideas resemble much practice theories according to which the meaning and use of things can only be understood in relation to a certain practice. Things do not then interact with each other but *intra-act* (Barad's neologism) as part of the network of agencies. What follows is that "phenomena do not merely mark the epistemological inseparability of observer and observed, or the results of measurements; rather, *phenomena* are the *ontological* inseparability of agentially intra-acting components" (emphasis hers)(Barad, 2007, p.33). These ideas have much implications to the ways in which we understand possibilities for change and action.

Possibilities for change and action are not relational to any "thing" but about the possibilities for changing (i.e., *reconfiguring* (Barad, 2007)) the constitution of the phenomenon. By inscribing possibilities for change to the whole agentic constitution of the phenomenon, Barad escapes anthropocentric conception of change and action. She is able avert voluntarism according to which possibilities for change would more or less equate to human intention and will, but also to avert determinism in which change, and action would inevitably follow a certain path. Rather, what she argues is that possibilities for change and action resides in this (material) space of possible reconfigurations. "[W]hat is at stake is not the locus of agency, but rather the question of how 'arrangements that produce effective forms of agency' (Ibid.[Suchman, 2007],p. 242) emerge in ongoing work" (Mazmanian et al., 2014, p. 832). As such, her framework does not tell exactly which of the possibilities will become realized but defines the space in which this change will and can take place.

Despite that each intra-action reconfigures the phenomenon, the space of possibilities do not emerge afresh with each intra-action. For Barad the space of possibilities is strongly tied to the past mattering. All intra-actions that have taken place before are carried in the matter's history. Barad elaborates this with an example: "[a]s the rings of trees mark the sedimented history of their intra-actions within and as part of the world, so matter carries within itself the sedimented historalities of the practices through which it is produced as part of its ongoing becoming – it is ingrained and enriched in its becoming" (Barad, 2007, p. 180). Possibilities thus *enfold* rather than unfold (Barad, 2007). However, the path dependency does not mean that future reconfigurations could be predicted from the past with certainty, such that events and development would follow a certain predefined trajectory, but that each reconfiguration opens up new possibilities for intra-acting as other possibilities become closed. That is, possibilities evolve alongside with the world's dynamic and forever enfolding becoming.

## 3.2 Affordances and Agential Realism

Building on AR, I propose that *affordances can be defined as dynamic, polycentric, and enfolding space of possible reconfigurations*. To elaborate this definition, affordances (1) change across time and space but also in relation to other agencies that constitute a particular phenomenon (*dynamic*); (2) are enacted in networks of distributed and connected agencies that are significant only in relation to one another (*polycentric*); and (3) are shaped by past choices and actions (*enfolding*). I will elaborate these arguments by explicating affordances most of us are very familiar with and use every day – affordances of an Internet search engine.

Understanding affordances of a search engine requires accounting for a host of other agencies than just user and the object used to perform the search (e.g., a laptop, smart phone). Most of these agencies are not immediately visible and are often inscrutable. While users' earlier experiences and perceptions of the user interface of a search engine are certainly significant for the formation of affordances, the interface is merely a surface. What it hides underneath is not just the 'same' that is immediately visible – as one can expect when interacting with a simple object such as a stone or a chair – but a complex amalgam of advanced technologies, all sorts of materials, and other humans that all jointly constitute the search engine and create "a place in which to work, with its own specific materialities, constraints and possibilities" (Suchman, 2007, p. 3). The affordances are not merely an enactment in an *interaction* between a user and the interface but formed in *intra-actions* of a host of agencies of which not all are 'local' but distributed across space. Thus, in these settings, what an environment affords (as in Gibson's original formulation), is not merely that which is in the reach of an arm or physically present but in as much that which is invisible, physically distant, and technologically created. A mobile phone without a connectivity to the search engine would not afford searching nor would a search engine that has no connectivity to the content spread across websites. Explaining the formation of affordances thus requires considering not only geographical concerns but topological concerns – the relations between agencies and boundaries in between. (Barad, 2007). Affordances of a search engine become enacted in these polycentric networks of agencies.

The search engine is not merely a collection of connected passive objects in which affordances change only to the extent that we learn by using it (cf. Leonardi, 2011), but a complex and active amalgam of system designers, content producers, other users, cloud computers, and highly sophisticated algorithms that actively participate in shaping the search affordances. In the case of a search engine, algorithms are significant. Rather than being passive substrate, they are active and performative (Orlikowski & Scott, 2015). These algorithms take factors such as the users' physical location, today's active topics, popularity of search terms, the type of device used to perform the search, and our own past searches[3] to dynamically organize the list of results. By doing so, they actively contribute to performing invisible "search engine bubble" [4] that gives raise to different realities for each user based on their preferences. What the search engine affords for a specific user may thus be wholly different than for another user. To use Barad's terms, the search results are in a constant intra-active becoming. Explaining affordances requires accounting for this dynamicity.

The search is never started fresh but happens along a continuum of past searches and other activities of the user and other agencies (e.g., what content others create, what they search). These past activities are carried in the materiality of the search engine, or as Barad (2007) calls it, they become sedimented as part of its historicity that gives matter its processual nature. This historicity of matter limits the available options but simultaneously opens new opportunities. The user's preferences for the Democrats or the Republicans become a part of the search engine's "material sediment", part of its memory and become implicated in the future searches. Matter remembers (Barad, 2007). As such, the searches and the results are reciprocally intertwined such that user's past searches and the search results are in-

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[3] These algorithms are proprietary and inscrutable (Introna, 2015). The exact details of what matters and not when searching is not known by the public. Thus, the factors listed here are examples of possible things the algorithm may take in to account when dynamically sorting the search results. Indeed, search engine optimizers who seek to manipulate the search engine results for economic gains devote much time and effort to understand the algorithm in an effort to influence the search results.

[4] For more information about search engine bubble, see http://dontbubble.us/.

tertwined. In Barad's terms, the search engine affordances do not unfold but they *enfold* – they unfold by unfolding through one another. This enfolding, however, does is not a strict deterministic path dependency. Rather, it merely indicates that past choices are carried to present and that this historicity is itself an active agency in future becoming. Users can, for instance, learn to break the search engine bubble by using another search engine or using the search engine in private browsing mode.

I argue that these three aspects of affordances discussed above and elaborated with the search engine example are salient for explaining the dynamics of modern complex infrastructures. Next, I will use these ideas to illustrate the conception of affordances with empirical material from an ethnographic field work.

# 4 Illustrating Agential Realist Affordances

After theoretically and conceptually elaborating the affordances that built on AR, it is now possible to empirically illustrate these theoretical ideas. Due to space constrains and illustrative purpose of the following empirical vignettes, I omit detailed description of research approach, and, instead, focus on the illustrations. The illustrations build on an ethnographic research (Myers, 1999) I conducted between October 2014 and May 2015. The empirical material is primarily based on field notes and head notes (Schultze, 2000) collected through participant observations that took place on site and in situ (2-3 days a week and 8 hours on average, except between the holiday season from mid-December to mid-January). During this period, I followed the maintenance and repair work technicians perform in a smart infrastructure's centralized operations centre. The operations centre is located in Finland and used to ensure reliable and continuous operations of a smart power grid that distributes electricity in one of the largest cities in the country. While being one of the largest, it is still a small company employing only around 300 as the power distribution is divided to 80 different companies in a country that has less than 6 million population. The smart power grid they operate has an extensive history and dates back to the beginning of 20th century. During this period of time the grid has gone through gradual evolution from a grid that mainly powered lightbulbs to a grid that powers basically everything in our contemporary world. Thanks to technological advancements, or the "smart" capabilities, the technicians' work has become transformed such that the operations take place mainly from a centralized location. For the transformation of their work, two ISs have had the most profound impact. The Supervisory Control and Data Acquisition System (SCADA) and the Data Management System (DMS) are two separate but interconnected systems that provide the technicians' functions to monitor and control the flow of electricity through the smart grid. The SCADA is used to monitor and control certain important nodes in the grid (referred to as substations), whereas the DMS provides an overview of the topological configuration of the whole grid and its status that is overlaid on a map. The DMS uses colouring to indicate different circuits in the grid that allows the technicians to promptly see which substations feeds electricity to different parts of the grid. As such, what the technicians know about the grid at any particular time and the technologies through which they know are tightly entangled.

While the context is not the most typical context of IS use, it provides an interesting context for illustrative purposes. Such smart infrastructures entangle physical and virtual; they are combinations of the rigid, persistent, and non-malleable messy materials of the "real" world and volatile and nontangible material of the virtual world (Graham & Thrift, 2007). The ISs and the power grid are also tightly intermingled in such a way that it is practically impossible to separate the two as the operations of the grid are so dependent on the material arrangements formed by the ISs, mechanical switches, relays and so forth. As the illustrations show, the messy materialities of the infrastructure and the ways in which the contemporary technologies connect places and agencies shape affordances in important ways.

## 4.1 Illustration 1: Overheating

One of the common tasks the technicians perform is to remotely repair the smart grid. The technicians are often able to either fix the problem remotely or to at least restore the flow of electricity to all subscribers. Certain (older) parts of the smart grid are formed by air wires that are hanged to utility poles. While all new parts of the grid are implemented as ground cables that are dug underground, there are still significant parts of the grid that utilize air wires. Air wires are considered less reliable than ground cables, as they are more exposed to external contingencies than ground cables. A typical reason for a power outage is caused by a tree or a tree branch that falls on to the exposed wire and causes a short circuit (or a ground circuit). In such occasions, the protective mechanisms built-in to the grid disconnect electricity from the wire in order to avoid any damage to the equipment. What also takes place within milliseconds is that the automation attempts to reconnect electricity back to the wire. This attempt, if successful, will restore the electricity so quickly that is not noticeable for the customers. If the attempt fails, the wire will remain without electricity. After a few seconds the technicians will seek to restore the electricity again. If the attempt is again unsuccessful they can determine that something is at least temporarily stuck on the wire. These attempts, however, will cause the electrical equipment to heat up and attempting to connect the electricity again would risk overheating the equipment and even cause the metal parts to melt due to the extreme heat caused by the short circuit. As such, the materiality of the grid and their past actions shape their affordances and the technology use. Their actions become intermingled with the messy and rigid materials of the smart grid. Only after allowing the equipment to cool down for few minutes it becomes possible to attempt to reconnect the electricity. The material components of the grid intra-act to resist action in relation to this specific practice of reconnecting electricity and necessitates this action of "non-action" (i.e., waiting for) to overcome the material resistance. As such, the affordances the IS provides cannot be isolated from the broader material network of agencies that form the grid. While these attempts to reconnect may sound irrational, they serve a purpose. For instance, if the outage is caused by a tree branch that has fallen on the air wires, connecting electricity may combust the tree branch and cause it to fall off from the wire thence fixing the issue.

## 4.2 Illustration 2: Safe operations

The smart grid is in need of constant maintenance. Most of this maintenance work requires that the field technicians physically visit the location, and for instance, clean the equipment from dust and grease mechanical components. In order to perform the maintenance work, those components that are under maintenance have to be cut from the flow of electricity to avoid the field technicians getting electrocuted. Due to the importance of electricity for our everyday lives, the maintenance work has to be planned in such a way that it creates as little downtime as possible to the flow of electricity. While the ISs enable the technicians to control the grid remotely and would allow them to disconnect electricity remotely, it is not used when maintenance work needs to be performed. Rather, the field technicians will themselves go physically to the location and use a special tool to manually turn a mechanical switch to disconnect the part of the grid from the flow of electricity after which they hang a bright yellow sign "Men at Work" on the switch. This manual operation of the switch and use of physical sign is considered to be safer than merely switching the power off from the IS. The mechanical disconnection and the yellow sign provides them with additional safety that the IS does not afford. However, when performing other tasks, it is the IS that affords additional safety. Such is the case when the field technicians have to operate certain old devices. Some of the devices, due to the long history of the grid, date back to 50s. Operating some of these devices locally can be hazardous if the mechanical parts no longer function as they should (also the design of these components was not as safety focused as it is nowadays). In such occasions, the technicians may use the IS to disconnect electricity from the unsafe equipment by operating some of the remotely controllable devices upstream from where the electricity flows. By doing so, they may disconnect the device from electricity before the field technicians manually operate the device.

### 4.3 Illustration 3: Material appurtenances

Performing maintenance of the grid involves coordinating both humans and technological devices. The technicians working at the operations centre perform coordination according to a premade plan that documents, in a standardized way, each step in a consecutive order. The DMS contains the plans in digital format and allows the technicians to see which step of the plan they are currently performing and the history of their past actions. However, when performing the coordination, the technicians use several other material artefacts through which the affordances for performing the coordination materializes.

Each plan is printed out before the execution of that plan. This affords the technicians to see the steps, but also to make notes with pen while they execute the steps. When performing the coordination tasks the technicians need to be mindful of the current state of the grid and of the aggregated history of changes and actions that they have taken before. To do so, they need to know different metrics that the ISs create for them about the current state of the grid, such as the current load on cables and on the grid in overall. Only by knowing these figures becomes it possible to perform certain operation as incorrect coordination has potential to cause severe damage – including loss of life. The technicians extend the affordances of the DMS by manually noting down these figures on the printed plans that they obtain from other systems (such as the SCADA). According to the technicians, the DMS itself does not provide them the necessary affordances for successful coordination but become jointly created in this network of printed plans, the DMS, and the SCADA. In addition, the technicians have paper-based log book to which they note every task that they have performed during their shift and all abnormalities and incidents they encounter when performing their work. This log book helps others to learn precariously the tasks other technicians have performed in past in an effective way. By learning about the past actions, the technicians become to know about the aggregated history of the changes that then provides them basis for their own subsequent actions when it is their turn to coordinate maintenance work.

## 5 Discussion and Conclusions

In this research I have proposed new foundations for the theory of affordances that builds on agential realist foundations. From agential realist perspective, affordances are not emergent properties of individual entities but about possibilities that pertains in networks of forever enfolding relationships. AR provides coherent foundations for affordances and also helps to draw attention to the complex networks of materialities that constitute affordances when interacting with infrastructures and technologies. Most centrally, AR draws attention (1) to the broader material constitution of the context of affordances; (2) to the dynamic and evolving nature of affordances through interaction (/intra-actions); (3) to the active nature of technologies and other material "objects" in the formation of affordances; and (4) to the path dependency of affordances. As such, this paper contributes to the discussions on affordances (e.g., Leonardi, 2011; Stoffregen, 2003; Stoffregen, 2004; Chemero, 2003; Pozzi et al., 2014), and more specifically to the ontological foundations of affordances (Robey et al., 2012; Volkoff & Strong, 2013; Fayard & Weeks, 2014) as well as to discussions on IS use (Straub & Giudice 2012; Burton-Jones & Grange, 2013). More broadly, this study contributes to the calls to study smart infrastructures and the IT capabilities in such settings (Constantinides & Barrett, 2016).

Relational view of affordances has broadly influenced IS research (Pozzi et al., 2014), but has lacked ontological foundations that build on relational ontology rather than on ontology of discrete entities. This is the main contribution of this research. From this perspective, "things" always exist only in relation to one another, and thus, AR allows to avert discussions on finding ways in which these two come together and combine. Instead, as pointed out by Bloomfield et al. (2010), "we need to talk instead of *how* and, importantly, *when* specific action possibilities emerge out of the ever-changing relations between people, between objects, and between people and objects". However, I have sought to show that by building on AR, not all objects are the same, and that also objects *intra-act* in ways that influence and actively shape the affordances.

AR extends past research on affordances with an alternative foundation that is apt to deal with the complexities of contemporary technology-enabled and “infrastructured“ world. As such, it is possible to extend the scope and applicability of affordances from its current use. I see that one of the risks of importing theories from ecological psychology is that we easily start using the original empirical examples that were concerned, not of interactions with complex technologies, but of interactions with simple objects, as analogous to contemporary technologies and to our interactions with those technologies. We see merely that which on the surface of technology (e.g., the interface) rather than the networks that constitute the technology and the affordances that are born out of those material constitutions. As such, AR may help us to untangle the black box of technology and not just the organization (cf. Zammuto et al., 2008) or “the network of [social] relationships and structures in a group and society” (Fayard & Weeks, 2014). Indeed, AR is likely to help us to focus on the environment as in Gibson’s original formulation rather than on a specific object that merely forms a part of that environment, and to acknowledge that the environment in these technology-enabled contexts is often more than just that which is in the reach of an arm.

Despite that scholars interested in IS use have mostly focused on the psychological antecedents of use[5], also context has played an important factor for studies focusing on IS use. However, context easily becomes reduced to the individual or social factors of the context (such as to frames (e.g., Orlikowski & Gash, 1994; Davidson, 2002) or culture (e.g., Rivard et al. (2011)) that only constitutes a part of any context. The empirical illustrations of this study suggest that understanding IS use may also require that more active part is given to the material context of the study, especially when dealing with smart infrastructure settings. The empirical findings show that IS use in smart infrastructure context shapes the material context itself and these changes become implicated in subsequent use patterns. This implies that affordances are not isolated from the materiality of the context but very much relational to it. Last, the way in which ISs are used may also be relational to other artefacts users have on their disposal. This is likely counter to the general belief that everything should be digitalized and that resorting to paper and pen is an indication of improper design of the IS. It might also be very well that what is needed is to recognize that not all affordances need to be constituted by digital technologies but by combinations of digital and non-digital technologies.

# References

Barad, K. 2003. "Posthumanist performativity: Toward an understanding of how matter comes to matter," *Signs: Journal of Women in Culture and Society* 28 (3), 801-831.

Barad, K.2007. *Meeting the Universe Halfway: quantum physics and the entanglement of matter and meaning*, London, UK: Duke University Press.

Barad, K. 2011. "Erasers and erasures: Pinch’s unfortunate ‘uncertainty principle’," *Social Studies of Science* 41 (3), 443-454.

Bloomfield, B., Latham, Y. & Vurdubakis, T. 2010. “Bodies, Technologies and Action Possibilities: When is an Affordance?,” *Sociology*, 44 (3), 415-433.

Boell, S. & Cecez-Kecmanovic, D. 2012. “Conceptualizing Information Systems: From ‘Input-Processing-Output’ Devices to Sociomaterial Apparatuses,” In *Proceedings of the European Conference on Information Systems*, 1-12.

[5] Any Technology Acceptance Model (TAM) (Davis, 1989) (or its derivate) based study could be cited here.

Burton-Jones, A. & Grange, C. 2012. "From use to effective use: A representation theory perspective," *Information Systems Research* 24 (3), 632-658.

Cecez-Kecmanovic, D. (2011). "On Methods, Methodologies and How They Matter," In *Proceedings of the European Conference on Information Systems*, 1-12.

Cecez-Kecmanovic, D., Galliers, D., Henfridsson, O., Newell, S. & Vidgen, R. 2014. "The Sociomateriality of Information Systems: Current Status, Future Directions," *MIS Quarterly* 38 (3), 809-830.

Constantinides, P., Henfridsson, O., & Parker, G. (2016). "Special Issue on Digital Infrastructure and Platforms," *Information Systems Research* (call for papers), 1-4.

Davidson, E. J. 2002. "Technology Frames and Framing: A Socio-Cognitive Investigation of Requirements Determination," *MIS Quarterly* 26 (4), 329-358.

Dolphijn, R. & van der Tuin, I.2012. *New Materialism: Interviews & Cartographies*, Ann Arbor, US: Open Humanities Press.

Emirbayer, M. 1997. "Manifesto for a Relational Sociology". *American Journal of Sociology* 103 (2), 281-317.

Faulkner, P. & Runde, J. 2013. "Technological Objects, Social Positions, and the Transformational Model of Social Activity," *MIS Quarterly* 37 (3), 803-818.

Fayard, A.-L. & Weeks, J. 2007. "Photocopiers and water-coolers: The affordances of informal interaction," *Organization Studies* 28 (5), 605-634.

Fayard, A.-L. & Weeks, J. 2014. "Affordances for practice," *Information and Organization* 24 (4), 236-249.

Feldman, M. & Orlikowski, W. 2011. "Theorizing Practice and Practicing Theory," *Organization Science* 22 (5), 1240-1253.

Gibson, J. J.1979. *The ecological approach to visual perception: classic edition*, Boston: Houghton Mifflin.

Graham, S. & Thrift, N. 2007. "Out of order understanding repair and maintenance," *Theory, Culture & Society* 24 (3), 1-25.

Introna, L. D. 2015. "Algorithms, Governance, and Governmentality: On Governing Academic Writing," *Science, Technology & Human Values* 41 (1), 1-33.

Jones, K. S. 2003. "What is an affordance*?," Ecological psychology* 15 (2), 107-114.

Jones, M. 2014. "A Matter of Life and Death: Exploring Conceptualizations of Sociomateriality in the Context of Critical Care," *MIS Quarterly* 38 (3), 895-A6.

Lanamäki, A., Thapa, D., & Stendal, K. (2015). "What Does a Chair Afford? A Heideggerian Perspective of Affordances," *Information Systems Research Seminar in Scandinavia* 6 (2015), 1-13.

Latour, B.2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*, Oxford, UK: Oxford University Press.

Lemke, T. 2014. "New Materialisms: Foucault and the 'Government of Things'," *Theory, Culture & Society* 32 (4), 3-25.

Leonardi, P. 2011. "When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies," *MIS Quarterly* 35 (1), 147-167.

Mazmanian, M., Cohn, M. & Dourish, P. 2014. "Dynamic Reconfiguration in Planetary Exploration: A Sociomaterial Ethnography," *MIS Quarterly* 38 (3), 831-848.

Monteiro, E., Pollock, N., Hanseth, O. & Williams, R. 2013. "From artefacts to infrastructures," *Computer supported cooperative work (CSCW)* 22 (4-6), 575-607.

Myers, M. 1999. "Investigating information systems with ethnographic research," *Communications of the Association for Information Systems* 2 (23), 1-20.

Niemimaa, M. 2016. “Sociomateriality and Information Systems Research: Quantum Radicals and Cartesian Conservatives,” *DATA BASE for Advances in Information Systems*, 47 (4), pp. 45-59.

Østerlie, T., Almklov, P. & Hepsø, V. 2012. “Dual materiality and knowing in petroleum production,” *Information and Organization*, 22 (2012), 85-105.

Orlikowski, B. 1991. “Studying Information Technology in Organizations: Research Approaches and Assumptions,” *Information Systems Research* 2 (1), 1-28.

Orlikowski, W. & Scott, S. V. 2015. "The Algorithm and the crowd: Considering the materiality of service innovation," *MIS Quarterly* 39 (1), 201-216.

Orlikowski, W. J. & Gash, D. C. 1994. "Technological Frames: Making Sense of Information Technology in Organizations," *ACM Transactions on Information Systems (TOIS)* 12 (2), 174-207.

Orlikowski, W. J. & Iacono, C. S. 2001. "Research commentary: Desperately seeking the" IT" in IT research—a call to theorizing the IT artifact," *Information systems research* 12 (2), 121-134.

Orlikowski, W. J. & Scott, S. V. 2008. "10 Sociomateriality: Challenging the Separation of Technology, Work and Organization," *The Academy of Management Annals* 2 (1), 433-474.

Rivard, S., Lapointe, L. & Kappos, A. 2011. "An Organizational Culture-Based Theory of Clinical Information Systems Implementation in Hospitals," *Journal of the Association for Information Systems* 12 (Special Issue), 123-162.

Robey, D., Raymond, B. & Anderson, C. 2012. "Theorizing information technology as a material artifact in information systems research," In *Materiality and organizing: Social interaction in a technological world*, 217-236.

Rouse, J. 2004. "Barad's Feminist Naturalism," *Hypatia* 19 (1), 142-161.

Sacks, O.1985. *The man who mistook his wife for a hat: And other clinical tales*, London, UK: Touchstone.

Schultze, U. 2011. “The Avatar as Sociomaterial Entanglement: A Performative Perspective on Identity, Agency and World-Making in Virtual Worlds,” In *Proceedings of the International Conference on Information Systems*, 1-18.

Schultze, U. 2000. "A confessional account of an ethnography about knowledge work," *MIS quarterly* 24 (1), 3-41.

Scott, S. V. & Orlikowski, W. J. 2014. "Entanglements in practice: Performing anonymity through social media," *MIS Quarterly* 38 (3), 863-893.

Stoffregen, T. A. 2003. "Affordances as properties of the animal-environment system," *Ecological Psychology* 15 (2), 115-134.

Stoffregen, T. A. 2004. "Breadth and limits of the affordance concept," *Ecological Psychology* 16 (1), 79-85.

Straub, D. & del Giudice, M. 2012. "Editor's Comments: Use," *MIS Quarterly* 36 (4), iii - viii.

Suchman, L. A.2007. *Human-Machine Reconfigurations: Plans and Situated Actions*, Lancaster University, UK: Cambridge University Press.

Tilson, D., Lyytinen, K. & Sørensen, C. 2010b. "Desperately seeking the infrastructure in IS research: conceptualization of" digital convergence" as co-evolution of social and technical infrastructures," In *Proceedings of 43rd Hawaii International Conference on System Sciences (HICSS)*, 1-10

Tilson, D., Lyytinen, K. & Sørensen, C. 2010a. "Digital Infrastructures: The Missing IS Research Agenda," *Information Systems Research* 21 (5), 748-759.

Volkoff, O. & Strong, D. M. 2013. "Critical Realism And Affordances: Theorizing It-associated Organizational Change Processes.," *MIS Quarterly* 37 (3), 819 - 834.

Wynn, Jr., D. & Williams, C. K. 2012. "Principles For Conducting Critical Realist Case Study Research In Information Systems," *MIS Quarterly* 36 (3), 787 - 810.

Zammuto, R. F., Griffith, T. L., Majchrzak, A., Dougherty, D. J. & Faraj, S. 2007. "Information technology and the changing fabric of organization," *Organization Science* 18 (5), 749-762.