

# IT's a Matter of Trust

## by Mary C. Lacity, Sebastian W. Schuetz, Le Kuai, and Zachary R. Steelman

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# Abstract

Trust is one of the most important constructs for understanding the adoption of information technologies (IT). In this chapter, we provide a review and analysis of the research on the construct of human trust in IT artifacts and in the entities that source, operate, and govern IT. We first take a broad view of the trust construct from multiple academic disciplines and from the Linux Foundation's Trust over IP (ToIP) white papers to gain a deeper appreciation of trust's complexities. We identified 13 assumptions about the nature of trust:

- 1. Trust is psychological.
- 2. Trust is social.
- *3. Trust is contextual.*
- *4. Trust involves expectations.*
- 5. *Trust involves vulnerability and dependency.*
- 6. *Trust involves promises, commitments, and obligations.*
- 7. Trust involves risks.
- 8. Trust is multidimensional.
- 9. Trust is limited.
- 10. Trust is dynamic.
- 11. Trust may be reciprocal, mutual, or asymmetrical.
- 12. Trust is transitive, to a degree.
- 13. Trust and distrust are different constructs.

Then, we analyze and discuss findings from how information systems (IS) scholars have defined, assessed, and measured trust within 214 articles published in the AIS Senior Scholars' Basket of Eight journals. Our review found that IS scholars have done commendable work on the construct of trust, particularly as it relates to Assumption #3—trust is contextual. IS scholars have examined trust in the contexts of blogging, corporate social responsibility, crowdfunding, e-commerce, e-government, e-healthcare, e-trading, e-voting, electronic auctions, electronic marketplaces, enterprise systems, identity management, Internet use, interorganizational systems, mobile applications, offshoring, open-source software, outsourcing, phishing, privacy, recommendation agents, social networks, virtual teams, virtual worlds, and websites. As a group, IS scholars have also deeply examined the multi-dimensional aspect of trust (Assumption #8) by examining different types of trust, including affective trust, swift trust, disposition to trust, trusting beliefs, and more. IS scholars have also done admirable work on Assumption #10—trust is dynamic. The body of work includes many qualitative papers that examined trust as a process. While the IS community can be proud of its cumulative tradition on the construct of trust, there is still interesting work to be done. We encourage more research on trust in emerging technologies, in bi-directional relationships, on the limits of transitive trust, and on the construct of distrust.

Keywords: Trust, Information Technology, Information Systems, IT Artifacts

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# Introduction

When we read a statement like "Alice trusts Bob", we have a comfortable understanding of what that statement means. Trust is a familiar, ordinary, common, and meaningful word used in everyday life. The angst over the concept of trust only begins when we assume our roles as scholars.

Because trust is essential to every part of the human experience, scholars in the disciplines of psychology, sociology, economics, political science, computer science, information systems, marketing, management, as well as other disciplines have studied trust (e.g., Alesina and La Ferrara 2002; Dirks and Ferrin 2001; Molm et al. 2000; Williamson 1993). Despite all the research on trust, scholars from within and across disciplines still struggle to find a commonly accepted definition of the construct. We aim to better understand how scholars from across fields and within the field of information systems (IS) define and measure trust.

Our research began with over 60 academic definitions of trust from psychology, sociology, computer science, economics, information systems and management. The common concepts across all trust definitions are (1) the presence of a human subject (sometimes called a trustor) who forms a trust perception and (2) the object of the subject's trust (sometimes called a trustee). Despite this commonality, we uncovered nuances across definitions of trust. We extracted 13 assumptions that offer rich insights into the complex nature of trust. Together, these assumptions presume that trust is a uniquely human experience (animal psychology is not considered in this paper) and thus only a human being may be the subject/trustor—things cannot trust. Objects of trust can occur at many levels, including a subject's trust in another individual, group, organization, or society (Li and Betts 2003). Subjects/trustors may also trust a thing, such as a policy or an IT artifact (e.g., Gefen et al. 2003; Jarvenpaa and Leidner 1999; McKnight et al. 2020; Pavlou and Gefen 2004).

Over 200 empirical articles in AIS Senior Scholars' Basket of Eight journals studied trust.<sup>1</sup> Summarizing the ways IS scholars measure the concept of trust is challenging because the terminology and/or measures are inconsistent. To find a consistent way to summarize how IS scholars measure the construct of trust, we used the method developed by Jeyaraj et al. (2006). The method entails developing a common vocabulary, mapping papers to the common vocabulary, and validating the mappings with a sample of the authors of the papers we mapped. Then we identified the most frequent measures of trust in IT artifacts, as well as trust in the institutional safeguards, humans, and entities that use, support, source, or govern IT. Across the 214 articles we coded, IS scholars assessed the object of a human's trust in IT artifacts in 75 papers, in a human, organization or collective in 218 papers, and in institutional safeguards in 12 papers. The total number of trust assessments are higher than the total number of papers examined because some authors

<sup>&</sup>lt;sup>1</sup> The eight journals are European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of the Association for Information Systems, Journal of Information Technology, Journal of Management Information Systems, Journal of Strategic Information Systems, and Management Information Systems Quarterly.

made multiple assessments/measurements of trust within a paper. As a body of work, the IS community has done significant research on the construct of trust, but there is still interesting work to be done.

# Assumptions about trust

We began our research by searching for scholarly definitions of trust in ABI/Inform and in the University of Arkansas library collections, focusing on peer-reviewed journals and scholarly books. We also examined the definitions and assumptions of trust identified by the Linux Foundation's Trust over IP (ToIP) community. This open-source community has written white papers about trust on the Internet. The lead author of this paper is a founding member and contributor. She brought the scholarly research on trust into the ToIP practitioner community, and by bringing ToIP into this scholarly work, we aim to crosspollinate ideas.

In total, we reviewed 63 definitions of trust. Scholars across disciplines have different assumptions and definitions of trust. For instance:

- Psychologists commonly consider trust as a personal trait or a psychological state comprising human attitudes, beliefs, and intentions (e.g., Dirks and Ferrin 2002; Johnson-George and Swap 1982; Rotter 1967).
- Sociologists often regard trust as a social construct that arises from social interactions (Blau 1964; Ekeh 1974).
- Economists, like Nobel Prize winner Oliver Williamson, often view trust as a mentally calculated probability of risk (Williamson 1993).
- In management, Mayer et al. (1995)'s conception of organizational trust comprising ability, benevolence, and integrity has dominated the study of trust in organizations.

As we will later show, IS scholars also widely adopted Mayer et al. (1995)'s conception to study trust in IT artifacts and in the entities that source, operate, and govern IT.

In reviewing the definitions of trust across disciplines, we uncovered 13 assumptions about the construct of trust (see Figure 1). We use the fictional scenario of Alice trusting Bob to aid comprehension (Rivest et al. 1978). While we do not claim the assumptions are exhaustive, they provide a rich understanding of the complex nature of trust.

For each assumption, we provide examples from at least two disciplines of how authors defined trust in their papers; sometimes authors appropriated prior definitions without alterations and sometimes authors extended prior definitions.

#### Figure 1: Assumptions about trust



In the scenario "Alice trusts Bob to collect her mail while she is on vacation," at least thirteen assumptions about trust inform our understanding.

- 1. Trust is psychological: Alice is a human.
- 2. Trust is social interaction: Alice may trust Bob (an individual), an entity, or a thing.
- **3.** Trust is contextual: Alice trusts Bob for a specific context, like collecting her mail during her upcoming vacation.
- 4. Trust involves expectations: Alice expects Bob to collect her mail during her vacation.
- 5. Trust involves vulnerability and dependency: Alice is vulnerable and depends on Bob to collect her mail.
- 6. Trust involves promises, commitments, and obligations: Alice believes Bob has made a commitment to collect her mail.
- 7. Trust involves risks: Alice incurs the risk that Bob may not collect her mail.
- 8. Trust is multidimensional: Alice makes multiple trust assessments of Bob; she might assess his competency, his good intentions, and his dependability.
- **9.** Trust is limited: Alice's trust in Bob is limited; she may not trust Bob to collect her mail everyday for the rest of her life, just while she is on vacation.
- 10. Trust is dynamic: Alice's trust in Bob is a process that may change overtime.
- **11. Trust may be reciprocal, mutual, or asymmetrical:** Alice trusts Bob, but Bob may not trust Alice.
- **12. Trust is transitive:** If Alice trusts Bob and Bob trusts Jane, Alice likely trusts Jane, to some extent.
- **13. Trust and distrust are different constructs**: Alice trusts Bob to collect her mail but Alice might distrust Bob in other contexts, like dating her daughter.

The assumptions are:

#### 1. Trust is a human psychological phenomenon.

**From an organizational psychology journal:** Trust is "*a personality trait of people interacting with peripheral environment of an organization.*" (Farris et al. 1973, p. 145)

**From a management journal:** *"Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another."* (Rousseau et al. 1998, p. 395)

**From a business and economics journal:** "Despite divergence in particular conceptualizations, most authors agree that, whatever else its essential features, trust is fundamentally a **psychological** state." (Li and Betts 2003, p. 106)

These three definitions of trust exemplify what we found in many other definitions of trust: nearly all scholars we reviewed assume that trust is a human psychological phenomenon based on human traits, beliefs, perceptions, judgments, and emotions (e.g., Dirks and Ferrin 2002; Hoffmann et al. 2014; Kramer 1999; Lewicki et al. 1998; Li and Betts 2003; Mayer et al. 1995; Moorman et al., 1992). Therefore, the scholarly literature commonly agrees that only a human can trust.

However, a few scholars argue that machines can be programmed to trust, such as by programming an artificially intelligent (AI) agent to make trust calculations about other users (e.g., Sabater-Mir and Sierra 2005). Porra et al. (2019) counterargue that programming computers to pretend that they are human endangers our humanness; the AI agents are not making trust assessments the way a human does—they are merely executing algorithms without emotions.

#### 2. Trust is a human social phenomenon.

**From a sociology journal:** "We define trust as expectations that an **exchange partner** will behave benignly, based on the attribution of positive dispositions and intentions to the partner in a situation of uncertainty and risk." (Molm et al. 2000, p. 1402)

**From an IS journal:** *"Trust is the willingness to rely on a business partner based on its past trustworthy behavior."* (Gefen et al. 2008, p. 531)

**From an IS journal:** "*Trust is a social construction that originates from interpersonal relationships.*" (Wang and Benbasat 2005, p. 74)

**From a business and economics journal:** *"Trust is relational… Without the involvement of others trust would not come into play."* (Li and Betts 2003, p. 106)

Many sociologists view trust—along with power, structures, and control—among the most important constructs indispensable to understanding social interactions and relationships (Blau 1964; Ekeh 1974; Giddens 1990). Many scholars assume trust is a social phenomenon because it arises from social dependencies, relationships, and exchanges (e.g., Coleman 1990; Kuang et al. 2020; Lewicki and Bunker 1996; Mayer et al. 1995). Because trust involves interactions, a trustor always has a trustee. The trustee might be another individual, an entity, or a thing. While some might argue that a "thing" is not social, "sociomateriality" recognizes the entanglement of social and material objects like technologies (Orlikowski 2007). IS scholars, as we have noted, regularly study IT artifacts as objects of trust.

## 3. Trust is contextual.

**From a psychology journal:** "[We]...conceptualize trust as a three-part relation involving properties of a truster, attributes of a trustee, and a **specific context** or domain over which trust is conferred." (Kramer 1999, p. 757)

**From a management journal:** "In general, trust refers to a positive expectation that one person has about another person's actions, intentions, or motives in a *specific context*." (Mayer et al. 1995, p. 714)

From a management book: "As social psychologists note, trust is expectations set within particular contextual parameters and constraints." (Lewicki and Bunker 1996, p. 116)

**From a ToIP white paper:** "*A trust relationship exists in a specific context, and it should not be assumed outside of that context. In other words, if A trusts B in context X, it does not mean A trusts B in context Y.*" (ToIP 2021b, p. 42)

Scholars generally agree that a subject trusts an object of trust for a specific context (e.g., Bachmann and Zaheer 2006; Mayer et al. 1995; Mayer and Gavin 2005; McKnight and Chervany 2002; Rousseau et al. 1998). If context matters, we can understand why different disciplines define and treat trust differently. For example, if Alice trusts Bob to pick up her mail but distrusts him to date her daughter, the process of trust formation in those two contexts might be very different.

## 4. Trust involves expectations.

From a management journal: "We define trust in terms of confident positive expectations regarding another's conduct." (Lewicki et al. 1998, p. 439).

**From a management journal:** Trust is "the extent to which one person can **expect** predictability in the other's behavior in terms of what is normally **expected** of a person acting in good faith." (Gabarro 1978, p. 294)

**From an IS journal:** *"Trust is a belief that trusted parties will behave in accordance with the trusting party's confident expectations by exhibiting ability, integrity, and benevolence."* (Fang et al. 2014, p. 413)

Many scholars define trust as a subject's expectation of the object of trust to do something in the future. Trust is always forward-looking, even if trust is informed by prior experiences (e.g., Fang et al. 2014; Li and Betts 2003; Mayer et al.1995; Rousseau et al. 1998; Sztompka 1999). Some scholars, however, argue that expectations are antecedents to trust rather than trust itself (e.g., Li and Betts 2003; Lewis and Weigart 1985). Either way, expectations are closely entangled with trust.

## 5. Trust involves vulnerability.

**From a management journal:** *"Trust is the willingness to be vulnerable* to another party when that party cannot be controlled or monitored." (Mayer and Gavin 2005, p. 874)

**From a psychology journal:** Trust is a "willingness to be vulnerable: this measure comprises items that express a willingness to allow oneself to become vulnerable to a partner." (Dirks and Ferrin 2002, p. 628)

Trust involves a human being's willingness to be vulnerable to the actions of other people or things (e.g., Das and Teng 2000; Dirks and Ferrin 2002; Lewicki et al. 1998; Mayer et al. 1995; Moorman et al., 1992). Vulnerability stems from dependency—the trustor depends on the object of trust to perform some action (Rousseau et al. 1998).

#### 6. Trust involves promises, commitments, and obligations.

**From a psychology journal:** "Interpersonal trust is defined here as an expectancy held by an individual or a group that the word, **promise**, verbal or written statement of another individual or group can be relied on." (Rotter 1967, p. 651)

**From a sociology book:** *"Social exchange requires trusting others to discharge their obligations."* (Blau 1964, pp. 93-94)

**From an IS journal:** *Trust is defined as "an individual or group makes good-faith efforts to behave in accordance with any commitments both explicit and implicit."* (Piccoli and Ives 2003, p. 366)

**From an IS journal:** *"Trust deals with the belief that the trusted party will fulfill its commitments despite the trusting party's dependence."* (Brown et al. 2016, p. 171)

Trust involves a human believing the promises, commitments, or obligations of the trustee to act in the trustor's interest, regardless of whether these promises, commitments, or obligations are explicit or implicit (e.g., Das and Teng 2000; Gambetta 1988; Guiso et al. 2004; Kramer 1999; Lewicki et al. 1998; Mayer et al. 1995; Moorman et al., 1992; Pavlou and Gefen, 2004).

#### 7. Trust involves risk.

**From a psychology journal:** "*The willingness to take risks may be one of the few characteristics common to all trust situations.*" (Johnson-George and Swap 1982, p. 1306)

**From a management journal:** *"Trust is a state involving confident positive expectations about another's motives with respect to oneself in situations entailing risk."* (Lewicki and Bunker 1996, p. 117)

**From a management journal:** *"Trust is a generalized behavioral intention to take risk."* (Mayer and Gavin 2005, p. 874)

The trustor always takes a risk because there is always the possibility that a trustee will not act in a dependable or trustworthy manner (e.g., Baier 1986; Mayer and Gavin 2005; Moorman et al. 1992).

#### 8. Trust is multidimensional.

**From a business and economics journal:** "*Trust is a multidimensional construct. Trust in a person could have various meanings simultaneously.*" (Li and Betts 2003, p. 104)

**From an IS journal:** "Although some researchers have treated trust as a unitary concept (e.g., Rotter 1971), most now agree that trust is *multidimensional.*" (McKnight et al. 2002, p. 335)

**From an IS journal:** "*Trust is widely conceptualized as a multidimensional construct that is composed of a set of trusting beliefs, namely, competence (ability of a trustee to effectively perform in a specific domain), integrity (adhering to principles generally accepted by a trustor, such as honesty and promise-keeping), and benevolence (caring and motivation to act in the trustor's interests).*" (Wang and Benbasat 2016, p. 745).

Trust is complex because subjects often make multiple trust assessments for one object (e.g., Mayer and Davis 1999; Mayer et al. 1995; McKnight et al. 2002; Vance et al. 2008). From the definition above by Wang and Benbasat (2016), we see an example of the appropriation of Mayer et al. (1995)'s multidimensional construct of organizational trust into the field of information systems.

#### 9. Trust is limited.

**From a political science paper:** "*Trust is seldom unconditional*; it is given to specific individuals or institutions over specific domains. For instance, citizens may entrust their lives to their government during wartime but not trust the bureaucracies that expend funds during peacetime." (Levi and Stoker 2000, p. 476.)

**From a ToIP white paper:** *"Trust is almost never unlimited. In the human perception of trust, every trust decision has a trigger point along a continuum that ends at a limit point. The limit point where risk exceeds reward."* ToIP 2021b, p. 44.

Most scholars argue that trust is usually, if not always, limited; a human being would rarely trust a trustee unconditionally (e.g., Barber 1983; Dirks and Ferrin 2001; Kramer 1999; Mayer et al. 2021). From the field of political science, the setting of term limits on holding political office is a prime example (e.g., Karp 1995; Levi and Stoker 2000).

#### 10. Trust is dynamic.

**From a management journal:** *"Trust changes over time-developing, building, declining, and even resurfacing in long-standing relationships..."* (Rousseau et al. 1998, p. 395).

**From management book:** *"Trust is viewed as a dynamic phenomenon that takes on a different character in the early, developing, and mature stages."* (Lewicki and Bunker 1996, p. 118)

While early studies of trust viewed trust as static (e.g., Axelrod 1984), modern scholars commonly view trust as dynamic (Chen et al. 2015; Fukuyama 1995; Lewicki et al. 1998 Rousseau et al. 1998). A trustor's trust of an object of trust changes over time—trust is a process. In the early developmental phases of trust, different types of trust may form, including swift trust, calculative trust, knowledge-based trust, and institutional trust (e.g., McKnight and Chervany 2002; McKnight et al. 2020; Pauleen 2003). Over time, relational trust may dominate (Rousseau et al. 1998; Robert et al. 2009; Li and Betts 2003) Trust can increase through positive experiences, but it can also decrease through negative experiences.

#### 11. Trust may be reciprocal, mutual, or asymmetrical.

**From a management journal:** There are "three approaches to understanding dyadic trust: **reciprocal trust**, wherein one party's trust influences the other party's trust; **mutual trust**, wherein both parties share a given level of trust that has important consequences for the dyad; and asymmetric trust, wherein each party has a different level of trust, and this disparity has consequences for the dyad." (Korsgaard et al. 2014, p. 47)

**From a ToIP white paper:** *"While many trust relationships are bi-directional, each direction is independent. In other words, if A trusts B, it does not mean B trusts A."* (ToIP 2021b, p. 41)

The academic research is inconclusive on whether trust is reciprocal, mutual, or asymmetrical. Korsgaard et al. (2014) reviewed 35 peer-reviewed papers on dyadic trust (trust between two parties). The authors summarized and critiqued the three ways scholars view trust within pairs. Reciprocal trust dominates the literature and is highly influenced by social exchange theory (Blau 1964). Reciprocal trust researchers have found that trust often converges over time, but even when reciprocal trust is present, within-dyad trust levels varied. Mutual trust recognizes that parties share a context that can signal cues that affect both parties' trust, that both parties are aware of each other's level of trust, and therefore trust decisions are correlated, not independent. Research on asymmetrical trust finds different levels of trust between parties, but the empirical work is limited. Korsgaard et al. (2014)'s review concludes, "One promising direction for moving the trust literature forward is more in-depth examinations of trust asymmetry and the variables and situations surrounding its existence." (p. 68)

#### 12. Trust is transitive to a degree.

**From an engineering/IS journal:** *"The transitivity property of trust captures the intuition that trust can be propagated along existing trust relationships. For example, if Alice trusts Bob and Bob trusts Carol, Alice might also trust Carol to some extent."* (Yao et al. 2014)

**From a science and medicine journal:** *"We will treat trust simply as a probability that a given assessment about an agent is true or false (e.g. fair/reliable or not); We further assume that this belief is transitive, i.e. if agent a trusts agent b, which in turn trusts agent c, then a will also trust c, to some extent."* (Richters and Peixoto 2011, p. 1.)

**From a ToIP white paper:** "In society today we have hundreds of ways to convey **transitive trust**. Governments, currencies, trademarks, diplomas, licenses—all of these are instruments that help us leverage the trust decisions made by other people or organizations. In fact, every credential you carry in your wallet is a tool for transferring some of the trust the issuer has in you, the holder, to a third party, the verifier." (ToIP 2021a, p. 7)

Scholars have examined transitive trust, particularly in the context of third-party reviews and recommendations and generally found that trust is transitive, at least to some degree (e.g., Agarwal et al. 2021; Bhuiyan and Josang 2010; Lifen 2008). Many sources argue that transitive trust has limits; long chains of trust can introduce new risks and weaken trust (e.g., Fernandes 2001; Lekkas and Grizalis 2004;

Webb 2008). Furthermore, transitive trust is not automatic—it's still a trust decision made by the trustor (ToIP 2021b).

#### 13. Trust is a different construct than distrust.

**From a management journal:** "We define trust in terms of confident positive expectations regarding another's conduct, and distrust in terms of confident negative expectations regarding another's conduct...." (Lewicki et al. 1998 p.439)

**From a management journal:** "Low distrust is not the same thing as high trust, and high distrust is not the same thing as low trust." (Lewicki et al. 1998, p. 444)

**From an IS journal:** "*Trust and distrust are crucial constructs for consideration.*" (Moody et al. 2017, p. 567.)

While some studies treat trust and distrust as opposite anchors on a trust continuum scale, scholars now widely agree that trust and distrust are different constructs with different antecedents and consequences (e.g., Dirks and Ferrin 2001; Gefen et al. 2003; Kramer 1999; Lewicki and Bunker 1996; Luhmann et al. 2021; Mayer et al. 1995; McAllister 1995; Moody et al. 2017). In general, trust involves positive expectations and emotions. Distrust involves negative expectations and emotions; distrust is not just low levels or the absence of trust (McAllister 2017). Some scholars even argued that trust and distrust are so independent that they can both exist in the same relationship (Chen and Chen 2019; Luhmann et al. 2021).

# The construct of trust in IS research

We now focus on how IS scholars have *assessed* trust in qualitative papers and how they *measured* trust in quantitative papers within the AIS Senior Scholars' Basket of Eight journals. We excluded papers that did not contain any empirical data, such as theorical papers, literature reviews, and editorials. For this chapter, we examined 214 papers (see Appendix A). Among these, 135 papers used quantitative methods, 63 papers used qualitative measures, and 16 used mixed methods. Figure 2 shows the number of articles by year published.

Summarizing the ways IS scholars conceive of and measure the concept of trust is challenging because the terminology and/or measures are inconsistent. For example, the following studies all measured trust in terms of a construct adopted from management comprising ability/competence, integrity, and benevolence but used different terminology, including "trusting beliefs" (e.g., Benlian et al. 2012), "trust" (e.g., Bhattacherjee 2002), "trustworthiness" (e.g., Crossler and Posey, 2017), "human-like trust" (e.g., Lankton et al. 2015), "cognitive trust" (e.g., Komiak and Benbasat, 2006), and "relational trust" (e.g., Venkatesh and Bala 2012).



Figure 2: Publication year of 214 papers that assessed/measured the construct of trust

We also found examples of using the same term but different measures. The most common example was the term "trust" itself which was consistently called "trust" but assessed or measured in many ways. Some IS scholars assessed trust in general without defining it for research participants, particularly when the research was qualitative; interviewees often brought up the notion "trust" (e.g., Pauleen 2003; Allen et al 2000). Other IS scholars measured trust quantitatively, either as a single construct with multiple items (e.g., Pavlou and Gefen 2005) or as a second order construct comprising multiple dimensions (e.g., Agarwal et al. 2021; Wang and Benbasat 2005).

We used the coding method developed by Jeyaraj et al. (2006) to aggregate how IS scholars assess/measure the construct of trust. Jeyaraj et al. (2006) applied the method to develop a common glossary to assess a large body of empirical research on the adoption of IT innovations. This method has also been used by other IS scholars to summarize the literature on business process outsourcing (Lacity et al., 2009; Lacity et al. 2011), mergers and acquisitions (Henningsson et al. 2018), and cloud computing (Schneider and Sunyaev 2016). This method allowed us to develop a common glossary (see glossary in Table 1) with which to code the papers.

	Construct	Definition	Sample sources
Object of trust	IT artifacts	As an object of a subject's trust, IT artifacts are products of human design that result in IT hardware or software, such as the Internet, a website, a trading platform, a mobile phone, or any other type of information system.	March & Smith 1995
	Human/ Entity	As an object of a subject's trust, a subject may trust an individual human or a group of humans, including organizations and collectives, such as an open-source community.	Brown et al. 2016
	Institutional Safeguards	As an object of a subject's trust, institutional safeguards capture the extent to which a subject believes that appropriate conditions are in place to facilitate successful transactions using an IT artifact; safeguards may include feedback technologies, escrow services, seals, endorsements, guarantees, or the reliance on trusted third parties to mitigate the subject's risks.	Connolly & Bannister 2007 Guo et al. 2018 Pavlou & Gefen 2004
<b>Operationalizations of trust</b>	Benevolence	The degree to which a subject believes that an IT artifact, human, or entity cares about and has good will towards them.	Mayer et al. 1995 McKnight et al. 2002
	Competence	The degree to which a subject believes that an IT artifact, human, or entity has the capabilities needed to perform a task or service well. This construct was sometimes called ability.	Mayer et al. 1995 Mayer & Davis 1999
	Compre- hensive trust:	A broad and deep assessment of a subject's level of trust, often operationalized as a second order construct comprising multiple sub-constructs.	Sollner et al. 2016 Wang & Benbasat (2008)
	General trust	The degree to which a subject generally reports trusting an IT artifact, human, entity, or institutional safeguards. For example, subjects often spoke about trust generally in qualitative papers without defining it.	Fitzgerald & Russo 2005 Oshri et al. 2007 Zimmermann et al. 2013
	Integrity	The degree to which a subject believes that an IT artifact, human, or entity adheres to strong moral principles, such as fairness, equality, and absence of bias.	Mayer et al. 1995 Mayer & Davis 1999
	Artifact- based trust	The degree to which the subject perceives that the IT artifact is dependable, reliable, helpful, functional, of high quality, and produces accurate and relevant outputs.	Everard & Galletta 2005 Fang et al. 2014 Rodon et al. 2011 Lankton et al. 2015
	Swift/Initial trust:	For new objects of trust, the degree to which a subject imports expectation of trust from other settings with which they are familiar.	Jarvenpaa & Leidner 1999

Table 1: Glossary on objects and operationalizations of trust

Using the glossary, we independently coded the subject of trust, the object of trust, and the operationalization of trust within each paper and met weekly to discuss our codes. We resolved any coding discrepancies with input from all four authors. Once consensus was achieved, we recorded the codes in a spreadsheet. After a few weeks, our independent codes became so consistent that we decided to assign two authors to code the qualitative papers and two authors to code the quantitative papers to increase our productivity.

We ensured the consistency and validity of our coding before moving to the data analysis stage. We assessed whether other researchers, using our glossary, would obtain comparable results. We reached out to authors most frequently seen in our sample and asked them to rate on a 7-point Likert scale with a 1 indicating "Strongly disagree" and a 7 indicating "Strongly agree" to what extent our codes and conceptual definitions represented their constructs fairly. Overall, we obtained ratings from 11 authors on 24 papers. The results showed strong agreement (mean = 6.42 out of 7), indicating high confidence in the validity of our coding.

Table 2 reports the 305 most frequent assessments/measures of trust.

Object Studied	Trust operationalized as:	Total		
	General trust in the IT artifact	37		
	Comprehensive trust - multiple dimensions of trust	21		
	Focused operationalizations of trust in the IT artifact:			
IT antifact	• Competence	7		
11 artilact	• Integrity	4		
	Artifact-based trust	4		
	Benevolence	2		
	Subtotal	75		
	General trust in a human or entity	116		
	Comprehensive trust - multiple dimensions of trust	45		
	Focused operationalizations of trust in a human or entity:			
Human/	Benevolence	20		
Entity	• Competence	24		
	Integrity	9		
	Swift/Initial Trust	4		
	Subtotal	218		
Institutional	General trust in the institutional safeguards	12		
safeguards	Subtotal	12		
saleguarus				
	TOTALS	305		

## Table 2 Scholar's most common assessments and measures of a subject's trust

Again, the numbers in Table 2 are higher than the total number of papers examined (n = 214) because some authors made multiple assessments/measurements of trust within a paper. (Table 2 does not include assessments/measures of trust that were found just once.<sup>2</sup>) Next, we explain the findings in Table 2 and provide examples.

**General trust in the IT artifact.** Focusing our attention on trust in the IT artifact as the object of trust, IS researchers most frequently assessed or measured general trust in the IT artifact (37 papers). In these papers,

<sup>&</sup>lt;sup>2</sup> Single assessments of trust not appearing in Table 2 include the following dimensions of trust in a human entity: affective, deceit, incompetence, malevolence, and reciprocity.

researchers were engaging with subjects and using the everyday language of trust as a familiar, ordinary, and common concept. As an example from a qualitative paper, Fitzgerald and Russo (2005) conducted a case study on the turnaround of the computer-aided dispatch system at the London Ambulance Service. The authors found that users trusted the relaunch of the system because they were included in the re-design.

As an example from a quantitative paper, Bansal et al. (2015) surveyed users to assess their overall level of trust in a website. They found a user's level of privacy concerns affected their levels of *trust*, which in turn affected their intentions to disclose private information.

**Comprehensive trust in the IT artifact.** IS researchers also commonly assessed or measured trust in the IT artifact comprehensively with multiple dimensions of trust, found in 21 papers. Several authors applied Mayer et al (1995)'s three dimensions of organizational trust (benevolence, ability, and integrity) to measure trust in an IT artifact (e.g., McKnight et al. 2017; McKnight et al. 2002; Wang and Benbasat 2008). For example, Wang and Benbasat (2008) conducted an experiment to assess users' trust in recommendations agents (i.e., Internet-based software programs) for e-commerce. They measured trusting beliefs as a multidimensional construct comprising benevolence, competence, and integrity. Among their many findings, the authors found that in the early stages of trust formation, knowledge about the software, interactive experiences with the software, calculative-based reasoning about its risks and rewards, and predisposition to trust were associated with higher trust levels.

**Focused operationalizations of trust in the IT artifact.** IS researchers have focused on particular aspects of trust, most commonly competence (7 papers), integrity (4 papers), IT artifact-based trust (4 papers) and benevolence (2 papers).

Once again, Mayer et al. (1995)'s three dimensions are evident on this list. In addition to treating competence, benevolence, and integrity as three sub-constructs in comprehensive measures of trust, some IS researchers also considered them as three separate constructs of trust with different antecedents and consequences. As an example from a quantitative paper, Komiak and Benbasat (2006) performed an experiment that measured users' cognitive trust in software-based recommendation agent's *competence* and *integrity*. They also measured emotional trust. The authors found that emotional trust played an important role beyond cognitive trust in determining users' intentions to adopt the software.

In a buyer-broker simulation, Xu et al. (2016) also measured *integrity, benevolence*, and *competence* as separate constructs and hypothesized different effects on user satisfaction and purchasing behavior. They found that benevolence positively affected user satisfaction and competence positively affected purchasing behavior.

As an example from a qualitative paper, Avgerou (2013) conducted a case study on e-voting in Brazil. Among her many findings, she found that a problem-free deployment enhanced people's trust in the *competency* of the system.

Four papers examined trust in the IT artifact by focusing on attributes such as quality, reliability, functionality and helpfulness. For example, Belanger and Crossler (2019) surveyed 288 iPhone users. The authors measured trust with three items that focused on the *reliability* of mobile phones. The authors found

that trust in the mobile phone's reliability positively affected the users' attitudes towards sharing information. Kim et al. (2009) measured initial trust in mobile banking based on the subject's perception of three measurement items: accuracy, reliability, and safety. The authors found that relative benefits, propensity to trust and structural assurances (i.e., institutional safeguards) affected initial trust in mobile banking.

**General trust in humans/entities.** IS researchers from 116 papers assessed or measured general trust in another human being, organization, or community. Many of these papers focused on the context of outsourcing IT services, global teams, or virtual teams. As an example of a qualitative paper, Zimmermann et al. (2013) used interviews to study how Germany-based clients felt about Indian-based developers. One subject explained that "initial performance difficulties were simply down to miscommunication" and he was inspired "to spend conscious effort in creating *trust* and setting up communication norms" (p. 76). Similarly, Oshri et al. (2007) used interviews to study how clients in one country worked with team members in another country. Subjects perceived that face-to-face team building exercises helped to established team trust. One subject said, "The team-building exercise was a way to show that we [headquarters] care about remote locations. The end result of that exercise was that the entire [globally distributed] team feels more comfortable to work together. Now we know each other and *trust* each other better." (p. 33)

**Comprehensive trust in humans/entities**. IS researchers also commonly assessed or measured trust in another human being, organization, or community comprehensively, found in 21 papers. Many of these papers are rich because they capture multiple types and sources of trust. For example, Sollner et al. (2016) looked at several types of trust, including trust in the Internet, trust in the information system, trust in the community of Internet users, and trust in the provider to determine their effects on user intention. Using a simulation experiment, the authors found that trust in the provider was as important as trust in the information systems in determining users' intentions.

**Focused operationalizations of trust on humans/entities.** Here again we see the prevalence of Mayer et al. (1995): IS researchers assessed a subject's trust in terms of separate dimensions for *benevolence, competence*, and *integrity*, with different antecedents and consequences. For example, Lioliou and Zimmermann (2015) conducted two case studies on vendor opportunism in IT outsourcing. The authors found that the client's positive past experiences with the vendor increased the client's trust in the vendor's *competence*. They also found that the relational dimension of social trust increased the client's "confidence belief that the other partner will be open and honest, and not harm other members of the network", which we coded as *benevolence*.

Four papers focused on *swift/initial trust* in a human being, organization, or community (Liu et al. 2017; Pauleen 2003; Jarvenpaa et al. 2004; Kanawattanachaia and Yoo 2002). For example, Kanawattanachaia and Yoo (2002) examined how swiftly two types of trust (cognitive and affective) were established in virtual teams. Using data from 36 MBA student teams competing in a web-based business simulation game, the authors found that high-performing and low-performing teams started with similar levels of trust.

Pauleen (2003) studied seven virtual team leaders to determine how they build relationships with team members. The author concluded, "*Swift trust* explains how virtual team members may be able to accomplish

tasks without first having developed personal relationships, and how this might be enough in certain conditions. Such trust appears to be fragile and temporary, however, and this study showed that the leaders tended to believe they needed to develop higher levels of relationship given the conditions present at the start of the team" (p. 244).

**Trust in institutional safeguards.** IS scholars assessed/measured a subject's general trust in institutional safeguards, such as seals, escrow services, guarantees, and the reliance on trusted third parties to mitigate counter party risks in 12 papers. For example, Pennington et al. (2003) measured systems trust in terms of seals, guarantees, and ratings and found that institutional safeguards were positively correlated with trust in the vendor. Kim et al. (2009) assessed subject's perceived structural assurances—which we coded as institutional safeguards—in the safeguards for mobile banking, such as guaranteed compensation for monetary losses that might occur during service usage. The authors found that institutional safeguards were positively associated with trust in mobile banking.

# Discussion

We now consider the body of work published in the AIS Senior Scholars' Basket of Eight journals against the cross-disciplinary assumptions from Figure 1. Our review found that IS scholars have done admirable work on the construct of trust, particularly as it relates to Assumption #3—trust is contextual. We find that IS scholars have considered many contexts, including blogging, corporate social responsibility, crowdfunding, e-commerce, e-government, e-healthcare, e-trading, e-voting, electronic auctions, electronic marketplaces, enterprise systems, identity management, Internet use, interorganizational systems, mobile applications, offshoring, open-source software, outsourcing, phishing, privacy, recommendation agents, social networks, virtual teams, virtual worlds, and websites.

IS scholars have also done considerable work on Assumption #10—trust is dynamic. The body of work includes many qualitative papers that used case studies to examine trust as a process (e.g., Avgerou 2013; Fitzgerald and Russo 2005; Oshri et al. 2007). While our analysis only took the coding up to 2019, we see excellent work on the construct of trust as a dynamic process continue. For example, McKnight et al. (2020) examined how trust changes in the context of news about new IT products using an experiment and surveys. The authors write, "[trust change] is crucial to companies like Google, whose new products like Google Glass and Waymo autos are covered widely by the press during beta testing, with each news article constituting an event that could help or hurt its future adoption." (p. 1017)

As a group, the IS scholars have examined the multi-dimensional aspects of trust (Assumption #8). Across papers, IS scholars studied different types of trust, including affective trust, cognitive trust, institutional trust, instrumental trust, intrinsic trust, knowledge-based trust, relational trust, swift trust, disposition to trust, trusting beliefs, and more. McKnight and Chervany (2002) concluded more than two decades ago a topology of trust is warranted. They developed an interdisciplinary model of trust that includes the disposition to trust construct from psychology and economics, institution-based trust from sociology, and trusting beliefs and intentions from social psychology and economics.

We have also noted the strong influence of Mayer et al. (1995)'s multi-dimensional construct of organizational trust (ability, benevolence, and competence) on IS research. Many IS scholars have applied

this multi-dimensional construct to assess trust in IT artifacts and in entities. While the appropriation of Mayer's work to assess entities that support IT seems valid, viewing IT artifacts as "benevolent" anthropomorphizes technology in a way that may endanger our humanness (Porra et al. 2019). In our opinion, IS research that examined the dimensions of trust in an IT artifact in terms of its quality, reliability, accuracy, and security seems a better fit for our discipline (e.g., Belanger and Crossler 2019; Kim et al. 2009; Lowry et al. 2013).

Finally, we acknowledge that our review has limitations. First, we only considered the work published in eight IS journals and only up until 2019; we inevitably missed some excellent scholarship. Second, in aggregating papers to find general patterns across papers, we lose the detailed richness of the work; there are always trade-offs to be made in sweeping views of a body of work.

# **Future research**

Despite all the work IS scholars have done on the construct of trust, we believe there is more to investigate. From our review of the assumptions of trust from across disciplines and of the empirical IS research in the AIS Senior Scholars' Basket of Eight journals, we offer the following suggestions:

We encourage IS scholars to continue researching trust in IT artifacts and in the policies, humans, organizations, and communities that enable them because contexts change. From Assumption #3, we assume that trust is contextual and therefore trust must be re-examined as new technologies and new ways to engage digitally emerge. Because IT evolves, we see a history of IS scholarship on the construct of trust. Early trust in the IT artifact studies focused an individual's willingness to use the Internet for shopping (e.g., Jarvenpaa and Todd 1996; Davis et al. 1999)—a research context that was quite new and important at the time. With the rise of global sourcing, virtual teams, and open-source software in the 2000s, IS scholars started to examine how trust is formed in these contexts, particularly focusing on trust in other humans, organizations, and collectives (e.g., Oshri et al. 2007; Zimmermann et al. 2013). Trust remains of perennial interest as new technologies emerge like blockchains, metaverse, generative AI, and Covid-19 contact tracing apps (Lacity 2022; Lacity et al. 2023; Laato et al. 2020). One recent paper by Seymour et al. (2021) examined the trustworthiness of avatars and found that subjects trust human realistic avatars more than non-human realistic avatars—the images in the paper are fascinating!

We encourage IS scholars to study bi-directional relationships between subjects and objects of trust.

Studies we reviewed regularly considered a subject's trust in a trustee, but not the trustee's trust in the subject. From Assumption #11, we know that the relationship between a trustor and a trustee is an open question in the management discipline. Researchers are not quite sure under which conditions relationships are reciprocal, mutual, or asymmetrical (Korsgaard et al. 2014). In the field of IS, there has been some work on mutual dependency, mutual understanding, and one-way trust in the context of outsourcing, mostly from the perspective of the client trusting the IT provider (Lacity et al. 2011). We found only a few papers that considered bi-directional trust. Bapna et al. (2017) examined trust, reciprocity, and forgiveness in social ties using a field experiment on Facebook. Guo et al. (2021) looked at how a sourcing platform (an example of an IT artifact) mediated trust between the client and sourcing provider. The authors found that governance of the platform was important for building mutual trust.

We encourage scholars to research the limits of transitive trust. From assumption #12, we assume that trust is transitive to a degree, but we do not know where the boundaries may lie and under what conditions. Scholars have studied "one hop" transitive trust, such as a subject's trust of a recommender or reviewer of a product, service, or vendor on an IT platform, but we did not find any research on longer transitive distances. On Facebook, for example, to what extent does a subject trust the friend of a friend of a friend of a friend...? On Linkedin, to what extent does a subject trust a colleague of a colleague of a colleague...? The limits of transitive trust is an important empirical question because hackers are known to exploit transitive trust (Webb 2008) and because some newer applications, like the Ripple and Stellar blockchain networks, find paths of transitive trust to process transactions that are more than a single hop (Lacity and Lupien 2022).

We encourage IS scholars to research distrust more. From assumption #13, we assume that trust is a different construct than distrust. Here we find a large gap in IS empirical work. In the AIS Senior Scholars' Basket of Eight journals, we found only eight papers that considered distrust (Charki and Josserand 2008; Dimoka 2010; Heiskanen et al. 2008; Lim et al. 2012; McKnight et al. 2017; and Moody et al. 2017ab; Wright and Marett 2010). McKnight et al. (2017), for example, studied both trusting beliefs and distrusting beliefs, and hypothesized different antecedents to each. However, the results showed high correlations; information quality and system quality were both negatively related to distrusting beliefs and positively related to trusting believes. One construct, service quality outcomes, was negatively related to distrusting believes, but had no significant effect on trusting beliefs.

Using an experiment with 632 students and a Delphi method to study susceptibility to phishing, Moody et al. (2017b) measured disposition to trust using the subconstructs benevolence, competence and integrity and the disposition to distrust using the subconstructs malevolence, incompetence, and deceit. The authors found that the constructs of trust and distrust did not significantly affect susceptibility to phishing. However, they found differences at the sub-construct levels that were interesting. Both malevolence and benevolence were negatively associated with susceptibility to clicking on a phishing text link from known sources. The authors concluded, "This is likely due to the mixed signals inherent within this situation. The source is known, and thus more likely to be trusted, yet the link is entirely unknown. Building on the work of Moody et al. (2017), we propose that the mixed signals cause the individual to engage in deeper processing, as both trusting and distrusting signals are present within the situation." (p. 574)

In conclusion, trust remains an important and relevant construct to understanding the adoption and use of IT artifacts and in the humans and entities that source, support, and govern IT. As our friends from the Trust over IP Foundation posit, "Technology can only help humans build trust if humans trust the technology." (ToIP 2021b. p. 51)

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#### Appendix A: AIS basket of eight papers included in our analysis

Agerfalk & Eriksson 2006 Agerfalk & Fitzgerald 2008 Al-Natour et al. 2011 Ali-Hassan et al. 2015 Allen et al. 2000 Altschuller & Benbunan-Fich 2013 Anderson & Agarwal 2011 Ang & Slaughter 2001 Arazy et al. 2010 Atkins 1998 Avgerou 2013 Awad & Ragowsky 2008 Ba & Pavlou 2002 Bala & Bhagwatwar 2018 Bansal et al. 2015 Bapna et al. 2017 Belanger & Carter 2008 Belanger & Crossler 2019 Benbasat & Wang 2005 Benlian et al. 2012 Bhattacherjee 2002 Bogusz et al. 2019 Breu & Hemingway 2004 Breward et al. 2017 Brown & Lockett 2004 Brown et al. 2016 Bunduchi 2005 Campbell et al. 2009 Carter & Belanger 2005 Carter et al. 2014 Chai et al. 2011 Chakraborty et al. 2010 Chan et al. 2010 Chandra et al. 2012 Chang et al. 2008 Charki & Josserand 2008 Chatfield & Yetton 2000 Cheng et al. 2016 Chiu et al. 2018 Cho & Mathiassen 2007 Cho et al. 2017 Choi et al. 2016 Connolly & Bannister 2007 Crossler & Posey 2017 Cyr 2008 Cyr et al. 2009 Dadgar & Joshi 2018 Davis et al. 1999 Dennis et al. 2012 Dimoka 2010 Dinev & Hart 2006 Dinev et al. 2006 Dube & Robey 2009 Everard & Galletta 2005 Fan & Lederman 2018 Fang et al. 2014 Fitzgerald & Russo 2005 Fox & Connolly 2018

Fuller et al. 2009 Gallivan & Depledge 2003 Gallivan 2001 Gefen & Pavlou 2012 Gefen 2004 Gefen et al. 2003 Gengatharen & Standing 2005 Gerlach et al. 2019 Goh & Wasko 2012 Goh et al. 2013 Goo et al. 2009 Gregory & Keil 2014 Gregory et al. 2013 Guo et al. 2018 Han et al. 2015 Heiskanen et al. 2008 Hess et al. 2009 Hoffmann et al. 2014 Hsiao 2003 Hsu & Chang 2014 Huang et al. 2003 Huang et al. 2011 Huber et al. 2013 Huber et al. 2017 Iacovou et al. 2009 Ibbott & O'Keefe 2004 Ibrahim & Ribbers 2009 Jain et al. 2011 Jarvenpaa et al. 2004 Kanawattanachai & Yoo 2007 Kanawattanachai & Yoo 2002 Karanasios & Slavova 2019 Kehr et al. 2015 Kelly & Noonan 2008 Kietzmann et al. 2013 Kim & Ahn 2007 Kim & Benbasat 2006 Kim & Benbasat 2009 Kim 2008 Kim et al. 2009 Kim et al. 2009 Kim et al. 2016 Klein & Rai 2009 Koh et al. 2012 Komiak & Benbasat 2006 Krasnova et al. 2010 Lankton et al. 2014 Lankton et al. 2015 Lankton et al. 2016 Lansing et al. 2018 Leclercq-Vandelannoitte et al. 2014 Lee & Choi 2003 Leimeister et al. 2005 Li et al. 2008 Lim et al. 2006 Lim et al. 2012 Lin & Armstrong 2019 Lioliou & Zimmermann 2015

Lioliou et al. 2014 Liu & Goodhue 2012 Liu et al. 2015 Liu et al. 2017 Lowry et al. 2008 Lowry et al. 2013 Lowry et al. 2015 Majchrzak et al. 2005 Malhotra et al. 2004 Mallat 2007 Matook et al. 2015 McGrath 2002 McKnight et al. 2002a McKnight et al. 2017 McKnight et al.2002b Miltgen & Peyrat-Guillard 2014 Mittendorf et al. 2019 Montazemi et al. 2012 Montoya et al. 2010 Moody Galletta et al. 2017 Moody Lowry et al. 2017 Nelson & Cooprider 1996 Nicholson et al. 2017 Nicolaou & McKnight 2006 O'Callaghan 2007 Oshri et al. 2007 Ou et al. 2014 Ozdemir et al. 2017 Panniello et al. 2016 Pauleen 2003 Pavlou & Dimoka 2006 Pavlou & Fygenson 2006 Pavlou & Gefen 2004 Pavlou and Gefen 2005 Pavlou 2002 Pavlou et al. 2007 Pennington et al. 2003 Persson et al. 2012 Porter et al. 2013 Posey et al. 2010 Qiu & Benbasat 2009 Qureshi et al. 2009 Qureshi et al. 2018 Rai et al. 2009 Redondo et al. 2009 Reinecke & Bernstein 2013 Ridings et al. 2002 Riedl et al. 2010 Robert et al. 2009 Rodon et al. 2011 Rose & Schlichter 2013 Rustagi et al. 2008 SANGSTER 1994 Sarker et al. 2011 Schlichter & Rose 2013 Scott 2000 Scott et al. 2016 Seltsikas & O'Keefe 2010

Shih et al. 2017 Sia et al. 2009 Simeonova 2018 Slavova & Karanasios 2018 Sollner et al. 2016 Son et al. 2005 Srivastava & Chandra 2018 Staples & Webster 2008 Stewart 2006 Sun 2010 Teo et al. 2008 Thomas & Bostrom 2010 Toppen et al. 1998 Tsatsou et al. 2010 Turel et al. 2008 van der Heijden et al. 2003 Van Slyke et al. 2006 Vance et al. 2008 Venkatesh & Bala 2012 Venkatesh et al. 2011 Venkatesh et al. 2016 Verhagen et al. 2006 Wagner et al. 2014 Wakefield 2013 Wang & Benbasat 2007 Wang & Benbasat 2016 Wang & Wang 2019 Warkentin et al. 2017 Watson-Manheim & Belanger 2007 Wright & Marett 2010 Xiao et al. 2013 Xu et al. 2012 Xu et al. 2016 Ye & Kankanhalli 2017 Zahedi & Song 2008 Zahedi et al. 2016 Zimmermann & Ravishankar 2014 Zimmermann et al. 2013 Zimmermann et al. 2018 Zviran et al. 2001