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Abstract

Decision situations are usually classified as decisions under certainty or uncertainty (risk) and considerable normative literature is available for guiding such decisions. Decision making under ambiguity, where ambiguity is operationalized as a "second order probability" or as a range of outcomes whose support may be unclear, is significantly different from risk and is receiving increasing attention in research. Most IS decisions, where little information is available about costs and benefits of alternatives are best characterized as decisions under ambiguity.

In this paper, we focus on the decision strategies/heuristics adopted by decision makers when a) cost information, and, b) benefit information of IT investments are ambiguous. In an ambiguous situation, decision makers are known to either prefer unambiguous alternatives over ambiguous alternatives (ambiguity avoidance) or discount ambiguity completely (ambiguity discounting) and treat outcomes as certain, based on context factors. We generate several hypotheses for the cases of decision making in dyads as well as a general business settings relevant to IS decisions.

Keywords: IS decision making, probabilistic ambiguity, outcome ambiguity, ambiguity avoidance, ambiguity discounting

Introduction and Research Question

Many decisions made in the IS domain involve situations where the costs and benefits are highly uncertain. For example, system costs typically include hardware, packaged software costs, licensing fees etc., which can be forecast with low variability. But the bulk of system development costs relate to system analysis/design/modeling, project management, implementation and user training, which are generally known to be highly variable and very difficult to estimate. While system costs show high variability, system benefits, because they are quite intangible, are even more variable. Generally speaking, the more strategic the system, the higher the variability in both costs and benefits. For example, in strategic decisions involving make-or-buy of enterprise systems, adoption of common technological standards across a firm, adoption of an enterprise-wide architecture, costs and benefits are almost impossible to estimate.

In IS literature, the terms uncertainty and/or ambiguity are used to communicate the notion that some significant aspect of IS decision is not really known or knowable. It is possible that, when we say we don't know (i.e., we are uncertain), it could mean several things i.e., there are *variants of uncertainty* (Kahneman and Tversky, 1982). We submit that adopting a more fine-grained distinction in the uncertainty construct in IS decision making can help understand practice as well as research.

The purpose of this research is to understand the implications of a variant of uncertainty, called *ambiguity* in literature, on IS decision making. We generate theoretical predictions about choices decision makers would make, when cost and benefit information is available in an ambiguous form.

Motivation

A very insightful observation about IS investments and the future of IS field is made by Markus (1996). Markus argues that IS investment is often viewed as infrastructure by CIO's and decision makers. Since there is no intrinsic value to an infrastructure, IS may be viewed as a "cost center" and the heuristic one would adopt in running a cost center is to minimize cost. The strategic benefits of IS investments may be ignored by decision makers.

In a working paper, Tanigawa (2004) points out that uncertainty is a significant issue in an important IS domain, enterprise architecture design. Tanigawa uses an interpretive, grounded theory approach to study the process by which enterprise architecture decisions are made in practice. She uses a sample of 20 enterprise architects from

Fortune 500 companies, with experience in IS field ranging from 10-25 years. Responses to questions in semi-structured interviews with the subjects are used as raw data.

When explaining their decision process and the rationale for their past decisions regarding enterprise architecture, many subjects in Tanigawa's study use the words: "not sure", "don't know", "not possible to know", "no one really knows", " ..reality is that nobody can measure it in the manner that everybody understands and agrees", "no answers are certain", "we haven't seen how a particular technology [reusable components] pays off" etc. This would recommend that practitioners are struggling with a form of uncertainty, which is difficult to articulate.

O'Leary (2001) presents the result of a survey conducted with practicing managers on ERP investments. Two of the interesting findings relevant to this study are: a) manager's estimation of benefits of ERP systems (Fig. 1), and b) risks perceived by managers (Fig. 2).

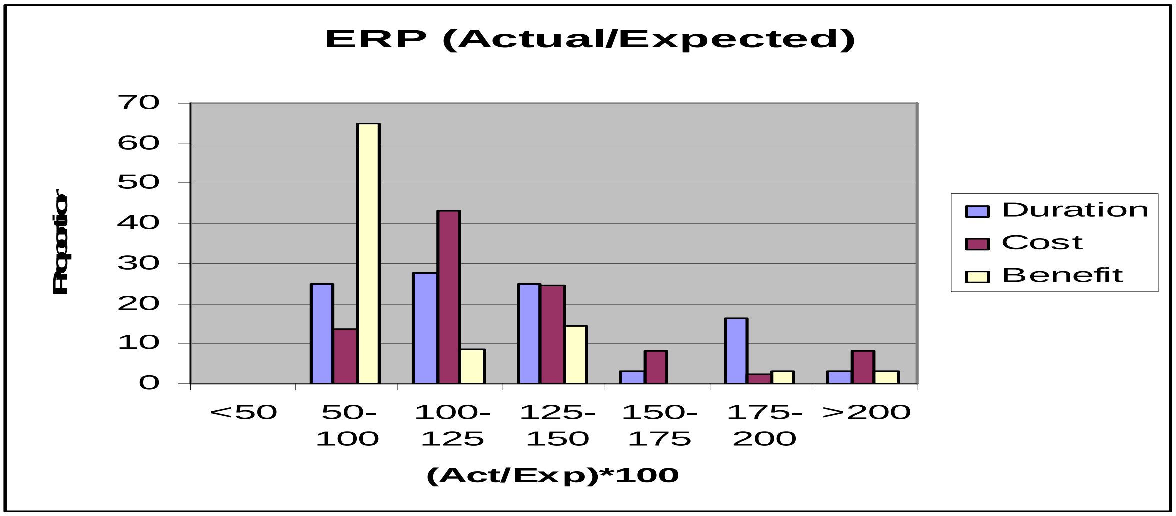

Figure 1. Actual versus Expected ERP Indicators (from O'Leary)

Fig. 1 shows that actual benefits are below expectations and actual costs are above expectations on an average, as is generally known. What is interesting is the distribution of overestimation of costs and benefits around the actuals (i.e., 100 on x-axis). Part of the reason may be motivational (i.e., IS managers may systematically oversell benefits and underesell costs), but it is also possible that a cognitive explanation may be warranted. Another interesting point made by O'Leary is that about 66% of managers do not even measure the benefits of ERP implementation!

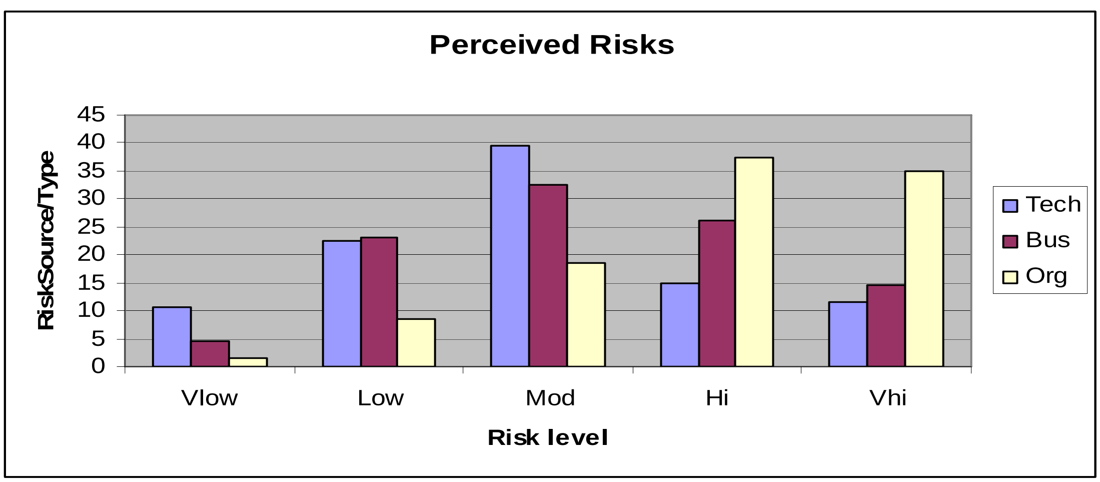

Figure 2. Risks Perceived by Managers Across Three Domains (from O'Leary, 2000)

Fig. 2 shows the distribution of perceived risks across technology, business and organizational domains. An interesting observation is that the less tangible factors (organizational followed by business followed by technical) have higher perceived risk level. For example, organizational factors surrounding ERP implementation are perceived to be riskier than technical factors.

Overall, prior IS research suggests that perception of IS (as a cost versus a strategic enabler) has an impact of how it will be managed (e.g., as a cost center). Tanigawa(2004)'s study shows not only that uncertainty is pervasive in enterprise architecture decisions, but also that it may not be easily captured by our simple notions of uncertainty. O'Leary's data (particularly, Fig. 2) suggests that the less tangible factors are considered more risky. Why it should be so is not clear from the data itself.

Literature Review

Theoretical Review on the Notion of Risk in IS (Brief)

Across many areas in business including the IS field, risk in general is viewed as an "expectation of a loss". We briefly discuss the work by Straub & Welke (2001) as a representative publication on the notion of risk in IS. Straub and Welke define risk as - "Risk is the uncertainty inherent in doing business; technically it is the probability associated with losses (or failure), multiplied by the dollar loss of the risk if realized." This conceptualization is analogous to the ideas from a well-known theory called (subjective) expected utility theory. Straub and Welke break down the risk into sub-risks such as system risk versus business risk and the central construct of their work, ***systems risk***, is defined as "the likelihood that a firm's information systems are insufficiently protected against certain kinds of damage or loss". Their model posits that manager's risk perceptions are a function of several context factors such as organizational environment, IS environment and individual characteristics. Using case studies, they develop a framework and a matrix which may be used to manager system risks. We observe that a) their notion of risk falls under the standard "expectation of loss" notion, and, b) they do not make a distinction between known risks and unknown/unknowable risks.

In an insightful paper, Ciborra and Osei-Jahane (2005) attempt to re-conceptualize the notion of risk as used in the IS discipline. They argue that, when novel corporate infrastructures (e.g., integration efforts such as EIS) are proposed, IS managers seem to use a narrow notion of risk. Such risk, called ***managerial risk*** by the authors, takes a control perspective and suggests that managers should follow the textbook approach for managing risk – i.e., risk definition, identification of cost-effective controls and the implementation of controls. The managerial risks, as defined by Ciborra et.al have a close resemblance to Straub and Welke's (2001) notion of systems risks. They argue that managerial risk concept is inadequate for gaining an accurate understanding of risk in complex IS efforts. They propose a notion of risk, called ***sociological risk,*** which includes "a due respect for the dynamics of side effects". They argue that, current focus in IS on managerial risk deals with "first order control of variances – anticipating disurbances, planning for reduction/elimination, acting upon the plans and on the basis of a feedback, managing them". In contrast, the sociological risk is conceived as a "second order risk" i.e., risk stemming from the control actions of the first order risk. Therefore, sociological risk, as conceived by Ciborra et.al., discusses "risks embedded in risk management" itself. Using several case studies, they show that sociological risk perception can provide an explanation for some unintended affects of IT risk management. We note that a) implicitly, the notion of "sociological risk" falls within an "expectation of losses" framework, and, b) they assume that the "second order" sociological risks are knowable.

In this paper, we use a notion of risk, called ambiguity in literature, in which some explicit information about a risk is unknowable. The classical work in this area is by Knight (1921) who distinguishes between risk and uncertainty. Under risk, a decision maker (DM) knows the probability with which an outcome occurs, while under ambuiguity, a decision maker does not. Indeed, some researchers argue that, beyond the coin toss and urn problems encountered in textbooks, it is unlikely that we would know the probability of an outcome in real life as a point estimate. Subsequent research on ambiguity, mostly based in psychology, operationlized ambiguity as ignorance about probability or ignorance about payoff. In this research, we use the notion of ambiguity and Table 1 below, summarizes the differences in conceptions of risk among the studies.

Table 1. Different Notions of Risk Used in IS Literature

Author (year)	Notion of Risk	Comments
Straub & Welke (1998)	Risk is an "expectation of loss" – a probability and a payoff, multiplied to yield an expectation. Risk is not explicitly distinguished from ambiguity/unknowability.	We use this article as "representative" of most IS work. This view, consistent with most intuitive notions of risk, is implicitly used in IS risk evaluations.
Ciborra & Osei-Joehene (2001)	Implicitly, sociological risk seems to fall under the standard "expectation of loss" frameowrk. Proposes a new notion of risk, called "social risk" – which may be viewed as "risk of risk control measures" They do not make a distinction between risk and unknowability	Ciborra & Osei-Joehene criticize a construct called "managerial risk" which is analogous to the "systems risk" construct used by Straub & Welke. The "social risk" is a new construct, but can lead to an "infinite regress" problem.
This manuscript	Risk is defined as a situation in which the payoff and the probability of an outcome are known up to a point estimate. Ambiguity refers to a situation in which either the probability of an event or the payoff are not known precisely. That is, some part of risk is not knowable.	We argue that: a) most IS risks, and risks in general, are not knowable. b) Behavior of decision makers, when faced with ambiguity may be different from that of risk. c) Some context effects matter and some hypotheses are developed.

Theoretical Literature on Rational Decision Making, Certainty, Risk and Ambiguity (Brief)

A significant criticism of Subjective Expected Utility theory, the bulwark of rational decision making (please see von Winterfeldt and Edwards for a review) was offered by Ellsberg (1961). A simpler version of the classic Ellsberg urn problem is summarized below (Winkler, 1991): Urn 1 (the ambiguous urn) contains 100 balls, each of which is either red or black, but one does not know the proportion of each color; Urn 2 (the unambiguous urn) contains exactly 50 red and 50 black bells. Betting on Red1 means that a ball will be drawn from Urn1 and if the ball is red, and the DM wins a prize. Subjects are then asked to indicate their preferences among the following sets of alternatives:

Red1 vs. Black1

Red2 vs. Black2

Red1 vs. Red2

Balck1 vs. Black2

Most people are indifferent between Red1 vs. Black1 and Red2 vs. Black2. In choosing between Red1 vs. Red2 or Black1 vs. Black2, however, most subjects prefer Red2 or Black 2 (the unambiguous urn). This general phenomena is called *ambiguity avoidance* and indicates that DMs generally avoid ambiguous alternatives. Ellsberg (1961, p. 657) defines ambiguity as "a quality depending on the amount, type, and 'unanimity' of information, and giving raise to one's degree of confidence in estimation of relative likelihoods". Following Ellsberg, considerable work has been done in psychology and economics on ambiguity and its implications for individual choices (e.g., individual differences in ambiguity aversion, impact of ambiguity on insurance decisions, bidding in sealed bid auctions, incomplete contracts, willingness to pay and willingness to accept, etc. – please see Camerer and Weber (1992) for a review). In applied and experimental research, ambiguity is defined with respect to both the probability of an event as well as its payoff. These are respectively called, *probabilistic ambiguity* and *outcome ambiguity*. In operationalizing a notion of ambiguity, researchers interpret inexact, incomplete, or vague information as ambiguous.

Since there is some inconsistency in usage of terms such as risk, uncertainty, ambiguity etc. in the literature, we summarize the terms as used in this paper below:

Table 2. Terms and Definitions

Term	Definition	Example
Certainty	The event is certain (probability = 1) and the payoff is a point estimate	$1 for sure
Risk	The probability of an event is known up to a point estimate and payoff is a point estimate	$2 with 0.5 probability, $0 with 0.5 probability
Ambiguity	General term for ambiguity. It usually implies that probability and/or outcome is not known up to a point estimate.	Knight (1921) calls this uncertainty – to avoid confusion, we will use the term ambiguity throughout the document. For example, Straub uses the term "uncertainty/ambiguity" and may be referring to risk, according to Knight's definition.
Probabilitistic ambiguity	Probability is not a point estimate, but a range of values.	Probability between 0.3-0.7 of a payoff of $1
Outcome ambiguity	Outcome is not a point estimate, but a range of values.	Payoff is between $1-$5 with a probability of 0.5

We discuss several systematic findings of this stream of research briefly here. One consistent finding is that, given a choice between an unambiguous and an ambiguous outcome, decision makers (DM's) prefer unambiguous outcomes over ambiguous outcomes (*ambiguity avoidance*). A second finding is that, in some cases, decision makers ignore ambiguity completely and pretend as if it doesn't exist (van Dijk and Zellenberger, 2003). For example, when an unambiguous and an ambiguous outcome are compared, a DM can ignore or discount ambiguous information and treat the ambiguous outcome as an unambiguous one. This heuristic is called *ambiguity discounting* in literature. This re-framing of ambiguity essentially results in a much simpler decision problem, but leads to further questions about the precise nature of discounting .

The main argument for ambiguity discounting is that ambiguity is cognitively difficult , because "it tends to blur the picture and makes it difficult for people to see through the implications of their outcomes" and also because "it assumes people to assume momentarily as true something that may in fact be false" (Tversky and Sattah, 1992). Van Dijk et. al. (2003) attribute ambiguity discounting behavior to two cognitive effects studied previously: the *disjunction effect* and *transaction decoupling* and provides detailed arguments.

Several individual differences and context effects may also contribute to how DM's respond to ambiguity. In an ambiguous situation (e.g., probability of an event is 0.4-0.6), the confidence that a DM has in her knowledge has a significant effect. The confidence of a decision maker, in turn could depend on the nature of the decision (e.g., a run-of-the-mill IS application versus a Greenfield application) as also on the confidence on the sources who provide probability and outcome estimates. An interesting implication of this result is that when a DM evaluates an ambiguous event in isolation, she may not exhibit ambiguity avoidance. Ambiguity aversion effect is strong in a comparative context in which an ambiguous and unambiguous artifact are compared, rather than in an unambiguous context when both objects are ambiguous.

Hypotheses

In this research, we argue that some of the risks faced by managers are unknowable and therefore, fall under ambiguity. An example of such a decision is whether a firm could standardize on the Jave/J2EE technologies or the

.Net family of technologies within a firm. This led to a very contentious debate among developers a few years ago when Microsoft launched the .NET family of technologies and even today, it is not clear whether one technology is clearly superior, in general (for a very hilarious industry discussion, please see http://www.gotdotnet.com/team/compare/petshop.aspx.). In general, for a majority of IS technologies, relevant information about probabilities and costs/benefits are rarely available at the time of a decision.

The first hypotheses stated below follows directly from prior research on ambiguity:

H1: *When presented with an ambiguous and an unambiguous alternative, subjects choose the unambiguous alternative (ambiguity avoidance)*

A more interesting questions from IS perspective focuses on comparing unambiguous alternatives. Fox and Tversky (1995) suggest that, when faced with two ambiguous alternatives (i.e., a comparative context), ambiguity avoidance disappears. Van Dijk et. al. (2003) suggest that decision makers may discount (i.e., completely ignore) ambiguity. Based on existing work, therefore, we state the second hypothesis as follows:

H2: *When presented with two ambiguous alternatives, subjects ignore ambiguity and choose an alternative based on net benefits.*

Beyond saying that ambiguity may be discounted or that it disappers, prior research does not really discuss what ***other heuristic*** may be used by a decision maker for comparing ambiguous alternatives. Since there is no existing theory with which to approach this question, we plan to test for a set of common-sense heuristics each of which represents a slightly different way of assessing net benefits. We list three heuristics in the following example:

Table 3. Possible Heuristics for Comparing Ambiguous Alternatives

Heuristic name	Description
Ambiguity avoidance	An unambiguous alternative is preferred over ambiguous one.
Ambiguity discounting	An ambiguous alternative is treated as if it is unambiguous.
ExpectedValue – MaxMin	Choose the alternative with the highest value of minimum net benefit
Expected Value - MaxMax	Choose the alternative with the highest value of maximum net benefit
Expected Value - RangeMin	Choose the alternative with the lowest range (MaxMax-MaxMin) in net expected value

Most IS decisions are made by groups or committees of people. Committee decision making is necessitated because often no single individual has a deep technical knowledge across all technologies involved and also because IS decision making involves other stakeholders such as end user managers. Keller et.al.(2002) conducted a study involving decisions made by two subjects working jointly (dyads) and find that a majority of dyads exhibit a more ambiguity averse behavior. This leads to the third hypothesis which states that:

H3: *Decision makers working in teams choose the less ambiguous alternative more often than individual decision makers.*

Most IS decisions are made in a business context which includes many other competitors who are also facing the same ambiguity. An argument made in literature is that, when faced with uncertainty, firm strategies will look similar because they imitate one another. In Institutional Theory from Sociology (Dimaggio and Powell) this phenomena is called *mimetic isomorphism* and Tingling and Parent (2002) find evidence of mimetic isomorphism in IS technology evaluation decisions. The question as to whether the system will settle down on a less ambiguous or more ambiguous alternative is not answered in this theory.

Fox and Tversky (1995) argue that people's confidence is undermined when they contrast their limited knowledge about an event with their superior knowledge about another event, or when they compare themselves with more knowledgeable individuals. They claim that this contrast in states of knowledge drives ambiguity aversion. In a business context in which many competitors are making judgments under ambiguity, if a decision maker feels that she has a comparable level of knowledge, she would not display ambiguity aversion. On the other hand, if a decision maker feels that her state of knowledge is inferior, she would choose the unambiguous alternative and avoid ambiguity. The hypothesis is stated as:

H4: *If a decision maker feels she has an inferior knowledge level compared to competitors, she will display ambiguity avoidance.*

Summary and Future Work

An interesting characteristic of IS investments is that the inputs to the decision, such as costs and benefits, are not known with certainty. We suggest that a variant of uncertainty, called ambiguity, may be an appropriate construct for IS decision situations. In the presence of ambiguity, decision makers may broadly choose to either avoid ambiguous alternatives (ambiguity avoidance) or discount it (ambiguity discounting), based on a variety of context factors, such as working individually versus teams, perceived state of knowledge and competitive situation. Based on prior research, we generate several hypotheses.

Status: We are currently working on generating further hypotheses. We plan to present the theory and hypotheses at the conference.

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