Towards the Development of a Taxonomic Theory

Full paper

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Abstract

Developing IS theories has been an important goal for many IS researchers. Towards that end, we discuss how taxonomic theory can be developed. According to Gregor, taxonomic theories are theories for analyzing, which she classifies as Type I Theory. More specifically, we show that some taxonomies, after meeting some conditions, can lead to taxonomic theory. Building upon a method for taxonomy development, we present a prescriptive framework for the development of taxonomic theory, which includes evaluation criteria for theorizing outcomes. To illustrate this, we present a taxonomy of an IS-related phenomenon (mobile applications) and then show how the taxonomy satisfies taxonomic theory requirements. In addition, we show how the development of taxonomic theory helps to analyze IS-related phenomena and how it can form the basis for more comprehensive IS-related explanatory, predictive or design theories.

Keywords

Taxonomies, theory, method, prescriptive framework, mobile applications.

Introduction

Taxonomies are useful ways of representing knowledge about objects in a domain. By classifying objects of interest, taxonomies can help explain similarities and differences among objects. Classification is often used to help order knowledge and provide a structure to an area (Glass and Vessey 1995). The uncovered order and structure allows researchers to investigate the relationships among other concepts within an area (McKnight and Chervany 2002). Taxonomies can also lead to discovery of missing objects in a domain and can lead to identifying and classifying new objects (Nickerson et al. 2013).

Taxonomies can have a more significant impact when they lead to theories. Gregor (2006) advanced this notion when she explains that taxonomies can be Type I or analytic theories, which analyze "what is" as opposed to explaining causality or attempting predictive generalizations. These most basic types of theories describe or classify specific dimensions and characteristics of individuals, groups, situations, events and information technologies, among others, by summarizing the commonalities found in discrete observations. These theories are needed when nothing or very little is known about the phenomenon in question, which is especially characteristic of new phenomena. These basic theories can also lead to the development of other types of theory that are common in information systems research. They also fit in the broader view that different types of theory exist in information systems and that all can be valuable (Gregor, 2006). Further, the objects of interest and empirically derived characteristics can imply that these are desirable factors in successful design, implementation and adoption of information systems, thus a Type I theory may also have implications of causality (Gregor 2006). When a taxonomy is a Type I theory, Gregor (2006) calls it a taxonomic theory. Developing taxonomies that lead to taxonomic theories is an important process. Taxonomy development has been studied extensively in many fields including biology (Eldredge & Cracraft 1980; Sokal & Sneath 1963), social sciences (Bailey 1994), and information

systems (Nickerson et al. 2013). Although valuable, this research has not provided an assurance that the resulting taxonomies will represent taxonomic theories.

We thus ask the following research questions: (1) Do existing taxonomies contain all structural components (described later) of a theory for analyzing (Type I theory)? (2) How do we evaluate a taxonomy that represents a theory for analyzing? (3) How can taxonomic theories provide a basis for other explanatory, predictive or design theories to explore IS-related phenomena?

To address these questions, we first examine the literature on taxonomic theories to identify the state-of-the-art for this type of theory. We note that classification schemes or taxonomy development schemes have been used in theory development (Doty & Glick 1994). Some of the developed taxonomies are analytic theories of Type I if they have all the structural components of Type I theory. Then, we present a prescriptive framework for developing analytic theory based upon a method for taxonomy development (Nickerson et al. 2013) to see if and how it contributes to the structural components of Type I theories. Most importantly, necessary and sufficient conditions are developed and included in the proposed framework as part of taxonomy evaluation. Using the evaluation criteria, we take an existing taxonomy and test if this meets all the conditions for being a taxonomic theory.

This paper is organized as follows. We first present theoretical background on analytic theory and identify necessary and sufficient conditions for a taxonomy to qualify as analytic theory. This is followed by two literature surveys of taxonomic theory papers and our analysis of the papers surveyed. We then present a prescriptive framework for analytic theory development. Then we demonstrate the effectiveness of our theorizing framework in the context of mobile applications and explain how the framework contributes to developing the structural components of an analytic theory. In addition, we show how the theory can form the basis for more comprehensive theory types in information systems (IS). We are not just interested in the outcome, but in the process of theorizing, which can be replicated and utilized by other researchers. We conclude the paper with discussion and suggestions for future research.

Theoretical Background

Theory is an abstract entity, an intermeshed set of statements about relationships among constructs that aim to describe, explain, enhance understanding of, and in some cases, predict the future (Gregor 2006). As Reynolds (1971, p. 11) explains, theories provide "(1) vague conceptualizations or descriptions of events or things, (2) prescriptions about what are desirable social behaviors or arrangements, or (3) any untested hypothesis or idea". The process of constructing or developing new theory often involves different forms of thinking and reasoning (Shepherd and Sutcliffe 2011).

Gregor (2006) presented five types of theories in information systems. The most basic of these are Type I or analytic theories. According to Gregor, analytic theories analyze "what is" as opposed to explaining causality, or providing predictive generalizations or prescriptions, which are characteristics of other types of theories. In the field of taxonomic theory development, this "discovery of new units to be employed in theory building is basically achieved through a process of classification" (Dubin 1978, P.79). Thus, analytic theories describe or classify the dimensions and characteristics of the phenomenon of interest (individuals, groups, situations, events, IT artifacts, etc.) by providing a description and analysis of the similarities and differences in observations of the phenomenon. These theories are needed when nothing or very little is known about the phenomenon in question and especially useful in emerging research fields. This most basic type of theory is useful for the development of other types of theory.

Gregor (2006) identified seven structural components of theories: means of representation, primary constructs, statement of relationships, scope, causal explanations, testable propositions, and prescriptive statements. Of these, only the first four apply to analytic theories. The remaining three are not present in analytic theories because these theories only describe and analyze; they do not explain causality, provide propositions for testing, or prescribe. These four theory components (TC1-4) are shown in Table 1 for an analytic theory (adapted from Gregor 2006). As scope is the most confusing component, we clarify that scope is a circle inside which the stated relationships among primary constructs are described by the theory. As additional primary constructs (or new artifacts or objects) are identified that also have the stated relationships, the scope will broaden. In the classical what, how and why questions related to theories (Whetten 1989), "what" and "how" describe and "why" explains. TC2 answers "what" factors should be considered in theory by considering both comprehensiveness and parsimony goals. TC3

answers "how" the objects are related by shared similar characteristics. Finally, TC4 answers "why" by providing assumptions and the logic underlying the theory. More specifically, TC4 explains the dynamics that justify constructs and relationships (Whetten 1989).

Theory Component	Instantiation
TC1. Means of representation	Words, diagrams, tables, taxonomic formulae
TC2. Primary constructs	Paradigms, approaches, methodologies, techniques, IS/IT artifacts
TC3. Statement of relationship	The classified objects within dimensions share similar characteristics.
TC4. Scope	Under explored artifacts within a domain of interest for IS. These artifacts follow the statement of relationship from TC3. A procedure to include new objects as they arise is included.

Table 1. Components of Theories for Analyzing

Although there are different instantiations of analytic theories, many use taxonomies as their means of representation. Gregor (2006) calls these taxonomic theories. Based on Gregor, taxonomic theory must, at a minimum, 1) be represented by a taxonomy and 2) describe and analyze a phenomenon of interest. These are the necessary conditions for a taxonomic theory, but they do not guarantee that any taxonomy is a taxonomic theory. First, whether something is a taxonomy is sometimes an open question. Many published "taxonomies" are merely simple classifications, sometimes in an N by N (N=2, 3, 4) format (Nickerson et al. 2013). Although there are many definitions of a taxonomy from biology (Sokal and Sneath 1963) and the social sciences (Bailey 1994), we prefer the following definition of a taxonomy, which has been used successfully for taxonomies in information systems (Nickerson et al. 2013): A taxonomy is a set of dimensions each consisting of a set of mutually exclusive and collective exhaustive characteristics. We formalize this definition later in this paper.

Second, judging whether the proposed theory describes and analyzes the phenomenon of interest can be highly subjective. Indeed, this question may be the critical one in the acceptance of a proposed analytic theory. We turn to Gregor again for help and propose that an objective way of looking at this question is in terms of the theory components shown in Table 1. The first component, means of representation, is satisfied by our definition of taxonomy. The remaining three components – primary constructs, statement of relationships, and scope – must be explicitly provided in the theory.

Gregor's four components do not guarantee that a taxonomy is a taxonomic theory, however. We argue that a taxonomic theory must provide a foundation for developing other theories, for, if not, the taxonomy, while useful (Nickerson et al. 2013), is merely a way of classifying objects of interest. As Gregor (2006) notes Type I theories are essential for the development of Type II, III, IV and V theories (Figure 1). In general, Type II, III and IV theories represent descriptive knowledge, while Type V represents more of prescriptive knowledge (Gregor and Hevner 2013). We illustrate how Type I theories can be evolve into Type II, III, IV and V theories in an example later in this paper.

This leads us to a set of sufficient conditions for a taxonomic theory. A taxonomic theory must 1) be represented by a taxonomy meeting our definition and satisfying four evaluation criteria (below) for a taxonomy 2) include the components of Table 1 in a way that completely describes the theory and 3) provide a foundation for developing other theories. Using high-level guidelines adapted from Gregor (2006, p. 624), we identify the following four taxonomy evaluation criteria: (a) usefulness (b) clarity of classification, (c) completeness and exhaustiveness, and (d) expandability. We note that these sufficient conditions are quite restrictive, and that there may be less restrictive sufficient conditions for a taxonomic theory. We leave this analysis for future research. We also note that these conditions may apply to other types of theories once causal explanations, testable propositions, and/or prescriptive statements are included. Further, multiple criteria for a theory, including novelty, importance, parsimony, and level (Weber 2012), could also be applied to taxonomic theory in the future.

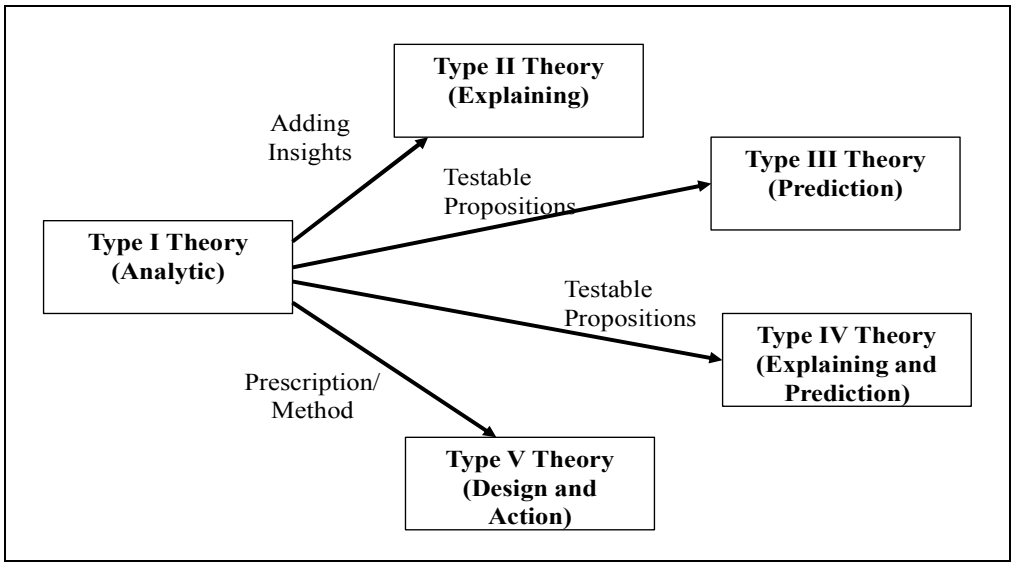

Figure 1. Evolution of Analytic Theories to Other Types (adapted from Gregor 2006)

Literature Surveys of Taxonomic Theory

We first conducted a literature survey of papers that have appeared in MISQ, ISR and JMIS until May 2014 and used the keyword "taxonomy". Our goal was to analyze these papers to see if any contained taxonomies that meet the requirements of a taxonomic theory. We found twenty papers with keyword taxonomy: ten from MISQ, two from ISR and eight from JMIS. The analysis of these papers is shown in Appendix A.

Of the twenty papers that we found, four do not have any of the four identified structural components of an analytic theory and so they are not listed in Appendix A. The remaining sixteen papers have one or more components, taken liberally, with explicit or implicit statements describing these components.

Seventeen of the twenty papers that we found do not focus on theory development. Out of these, eight papers, when taken liberally, mention theory development as a future research activity, while nine make no mention of theory development. The remaining three papers attempt to provide theoretical contributions from taxonomy. These attempts include (i) evaluating the success of systems implementation, (ii) testing of hypotheses, and (iii) classifying mechanisms as input variables. None of these paper mentions development of analytic or taxonomic theory as one of their goals.

Eight of the twenty papers do not focus on any type of taxonomy evaluation (usefulness, clarity, completeness and exhaustiveness, and expandability). Eleven do some informal evaluation, taken liberally, using one or more attributes, specially completeness or usefulness. Only one paper addresses evaluation of taxonomy explicitly. This paper utilizes statistical techniques for automatically generated taxonomy of documents. This paper does not focus on theory development.

We conducted another literature survey of papers on development of taxonomic theory. We identified the papers by searching the ISI Web of Knowledge (www.webofknowledge.com) with the search string "taxonomic theory".

We identified 26 relevant papers that used "taxonomic theory" in any form. We found that the phrase "taxonomic theory" has been used in developmental psychology, criminal justice, and sports science, among others. These papers refer to discipline specific theories such as Moffitt's Developmental Taxonomic Theory (Moffitt 1993) which characterizes the behavior of humans growing from childhood to various stages of development. Our context is on development of taxonomic theory from classification of objects and structural components of theories (Gregor 2006). We classified seven of the papers as related

to IS/DS/MS and nineteen as related to other disciplines. Further, two of the papers (including Gregor 2006) focused on development of Type I theory.

From this literature survey, we observe that

- Since we found 26 papers using the term "taxonomic theory" there is some name recognition for this term in published literature, although it is limited.
- Of the surveyed papers, nineteen either use Developmental Taxonomic Theory or just Taxonomic Theory to refer to (a) theory underlying taxonomy, (b) taxonomy of theories, or (c) theoretical research in different contexts.
- Of the remaining seven papers, only two deal specifically with taxonomic theory. One is Gregor (2006), which we have cited numerous times in this paper. The other is Saxon et al. (2013), which uses the phrase "taxonomic theory" to mean a comprehensive classification of all empirical attributes of crowdsourcing models. The other five papers only use the phrase once to imply that sound methods should be used in taxonomy development.

None of the 26 papers presents any method that uses or produces any structural components of Type I Theory (Gregor, 2006). None of these papers make any attempt to develop a taxonomic theory. None mention any theoretical development as their goal or output. No papers include a comprehensive evaluation of the produced taxonomies for the four attributes of (a) usefulness, (b) clarity of classification, (c) completeness and exhaustiveness, and (d) expandability. Based on these two literature surveys, we conclude that there is a need to address how taxonomic theory can be developed for emerging IS-related phenomena, about which little is known at this point, as many researchers will find such theories useful. Currently, there is not much guidance or support for developing taxonomic theories. We conclude that some guidelines and conditions, and even a framework for taxonomic theory development would be beneficial, especially for emerging areas of research. The guidelines and conditions we derive can lead a taxonomy to become taxonomic theory. Towards this, we present a prescriptive framework for taxonomic theory. The framework includes (a) process model (how to do), (b) guidelines and conditions (what to do) and (c) evaluation (when is taxonomy a taxonomic theory).

Theory Development

The process model for theory development used in this paper is shown in Figure 2. We show two possible paths for developing theories. The more typical theory development process is shown in the bottom half where the phenomenon of interest is observed and analyzed for some time, before researchers start developing theories for explaining the phenomenon and making predictions for future. One example for this kind of research is theory development that adapts constructs and theory from related disciplines (e.g. psychology or marketing) to the context of information systems.

The process we propose in this paper is shown in the top half of the Figure 2, where emerging IT-related phenomena can be studied using taxonomy development (iteratively). This process will lead to taxonomies, some of which will be taxonomic theories by meeting the necessary and sufficient conditions given previously. These theories can lead to testable propositions and eventually to explanatory, predictive or design theories (Type II, III, IV, or V theories). The development of taxonomic theory in the context of emerging information technology and the use of such theory to develop Type II and higher theories may also contribute to the development of the IS discipline.

When doing so, we argue that developing more comprehensive theories on the basis of IT-related taxonomic theories can contribute positively to the critical debate on the "missing IT" in IS research in general. Senior researchers have raised their concerns about the lack of centrality of IT in IS research (Orlikowski and Iacono 2001; Weber 2003). Overall, this debate opened up the discussion "that the field [i.e. IS research] has not deeply engaged its core subject matter—the information technology (IT) artifact" (Orlikowski and Iacono 2001, page 121). Instead, what we can see in publications in the major IS journals is that middle range theories including their constructs are adapted from other disciplines (e.g. from psychology or from marketing) in order to develop theory explaining IT-related phenomena. In contrast, building instead upon analytic theory with a focus on the IT artifact would provide a more IS-related basis

for any theorizing endeavor. Seen from this perspective, theory development would then benefit from building upon IT-related taxonomic theories. The development of taxonomic theory that describes novel IT-related phenomena could serve as a vehicle to develop new theory that "colleagues in other disciplines will acknowledge as belonging to the information systems discipline" (Weber 2003, page vi). Against this background, we proposed that our process model is useful, generally applicable, and expandable for development of analytic theory and may serve for theory development in general.

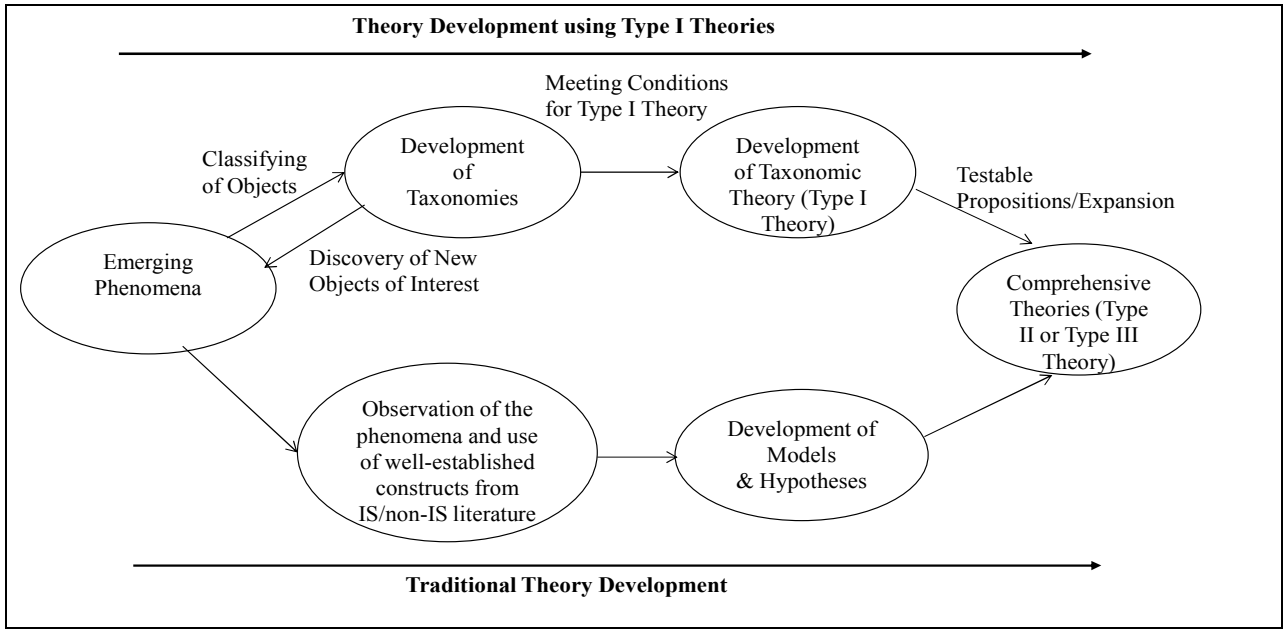

Figure 2. Developing IT-related Theory on the Basis of Taxonomic Theory

Prescriptive Framework for Taxonomic Theory Development

Methods for taxonomy development have been proposed in several disciplines. In biology, taxonomies may be developed using several approaches including phenetics or numerical taxonomy (Sokal and Sneath 1963) and cladistics (Eldredge and Cracraft 1980). In the social sciences, conceptual, empirical, and indicator or operational approaches may be used (Bailey 1994). In the information systems field, Nickerson et al. (2013) propose a method for taxonomy development that extends approaches in social science. In this paper, we build upon our understanding of analytic theory components (Gregor 2006) and taxonomy development methods (Nickerson et al. 2013) to present a prescriptive framework of theorizing for developing analytic theory.

Before we explain or framework for taxonomic theory development in detail, we first introduce two building blocks of our framework: First, we describe the core components of a taxonomic theory, i.e. the components any theorizing intention should deliver. Second, we introduce evaluation criteria, every developed taxonomic theory should satisfy.

Theory Components

The four components of an analytic theory shown in Table 1 can be instantiated as follows (based on Nickerson et al. 2013):

TC1. Means of Representation

A taxonomy, T, is represented formally as follows:

$T = \{Di, i = 1, \ldots, n \mid Di = \{Cij, j = 1, \ldots, ki, ki \geq 2\}\}$

where

Di = dimension i

Cij = characteristic j for dimension i

such that Cij (j=1, … , ki) are mutually exclusive and collectively exhaustive for dimension i.

TC2. Primary Constructs

The primary constructs are the objects of interest in a domain classified by the taxonomy.

TC3. Statements of Relationship

The relationships among the objects are expressed by inclusion or exclusion of objects in the various types identified by the dimensions and characteristics of the taxonomy.

TC4. Scope

The scope is expressed as absolute inclusion or exclusion of an object in a type. An object either is or is not a type. An object cannot be two different types. The scope can further limit all, many and some of the objects available in a domain (such as published literature). A procedure for adding more objects as they become available is also provided.

Evaluation Criteria

During the process of analytic theory development, the theorist should aim at building a theory that complies with the following criteria:

1. Usefulness: The classification system is useful in aiding analysis in that the category labels and groupings are meaningful and natural, and most important divisions are shown at the highest level.

2. Clarity of Classification: The logic for the placement of objects into categories should be clear, as should the characteristics that define each category. There should be decision rules, which are simple and clear to assign instances to classes and the classes should be mutually exclusive.

3. Completeness and Exhaustiveness: The important categories or elements should not be omitted from the classification system, that is, it should be complete and exhaustive.

4. Expandability: A classification system could be revised as new entities come to light, or a different way of grouping or naming categories is identified.

Prescriptive Framework

Any of the approaches identified here could be used for developing taxonomies in the context of IS-related phenomenon. Phenetics or numerical taxonomy from biology, which relies on statistical clustering, would suffice in situations involving significant data. The cladistics approach from biology may be harder to apply as it requires identifying evolutionary relationships, which may be difficult to find outside of the biological domain. The empirical approach in the social sciences is based on numerical taxonomy. The conceptual approach from social sciences could also be used as could Bailey's (1994) indicator or operational approach. We find, however, that the Nickerson et al. (2013) method includes elements of other approaches in a unified pattern that does not limit the researcher to one approach but rather allows the researcher to choose the best path or paths leading to the final classification (please see Appendix B). The richness and completeness of this method, as well as the fact that it has been demonstrated in information systems, leads us to select it for analyzing an IS related phenomenon. We also find that the steps in this method lead to the development of the structural components of a Type I or analytic theory and thus to a taxonomic theory. Table 2 lists these steps along with how they lead to the development of these structural components. The application in the context of an IS-related phenomenon is also shown in this table.

Steps of the Method for Taxonomy Development	More Details	Development of Four Structural Components of Analytic Theory	Application in Taxonomic or Analytic Theory
Formal definition of taxonomy	The formal definition of taxonomy provides a basis for the following development process.	Means of Representation- (TC1)	Adds dimensions and characteristics to the taxonomy
Determine meta-characteristics	Most comprehensive characteristic and serves as the basis for the choice of characteristics Should be based on the purpose of the taxonomy	Scope-Component (TC4)	Focuses on taxonomy & defines part of the scope (artifacts and their context of use)
Determine ending conditions	8 objective conditions: all objects, no merging/splitting last time, an object under every characteristic, no new dimensions or characteristics last time, no dimensions or characteristics merged or split, unique dimensions and characteristics and uniqueness of taxonomy cells	Scope-Component (TC4)	Allows completion of processing of objects and relationships (scope) in a reasonable time
Select an approach	To allow both inductive and deductive approaches and select one in each iteration based on the need to identify new objects or new characteristics at the time		Provides alternative approaches to the development of Taxonomic Theory (inductive and/or deductive approaches)
Empirical to conceptual • Identify new objects • Identify common characteristics • Group the characteristics to create taxonomy	From the known objects, derive common characteristics and then add that to the taxonomy for classification (with certain uniqueness requirements to avoid duplication or overlap)	Primary Constructs-Component (TC2) Statement of Relationship-Component (TC3)	Characteristics and Dimensions for Taxonomic Theory
Conceptual to Empirical • Identify new characteristics • Examine objects • Create taxonomy	Using the identified or desirable characteristics, find out which objects have which characteristics and then classify the objects under those characteristics	Primary Constructs-Component (TC2) Statement of Relationship-Component (TC3)	Characteristics and Dimensions for Taxonomic Theory
Test for ending conditions	Testing all eight objective conditions	Scope-Component (TC4)	To avoid unnecessary iterations when all objects and stated relationships (scope) have been analyzed

Table 2. How the Method Supports the Development of Taxonomic Theory

After presenting the details of prescriptive framework and evaluation, we present the process model as shown in Figure 3. The process model is iterative and shows various steps of development of taxonomic theory using the proposed framework. It follows all the steps identified in Table 2 and then moves to evaluate the taxonomy for necessary and sufficient conditions. If not met, the process moves to other steps and so on.

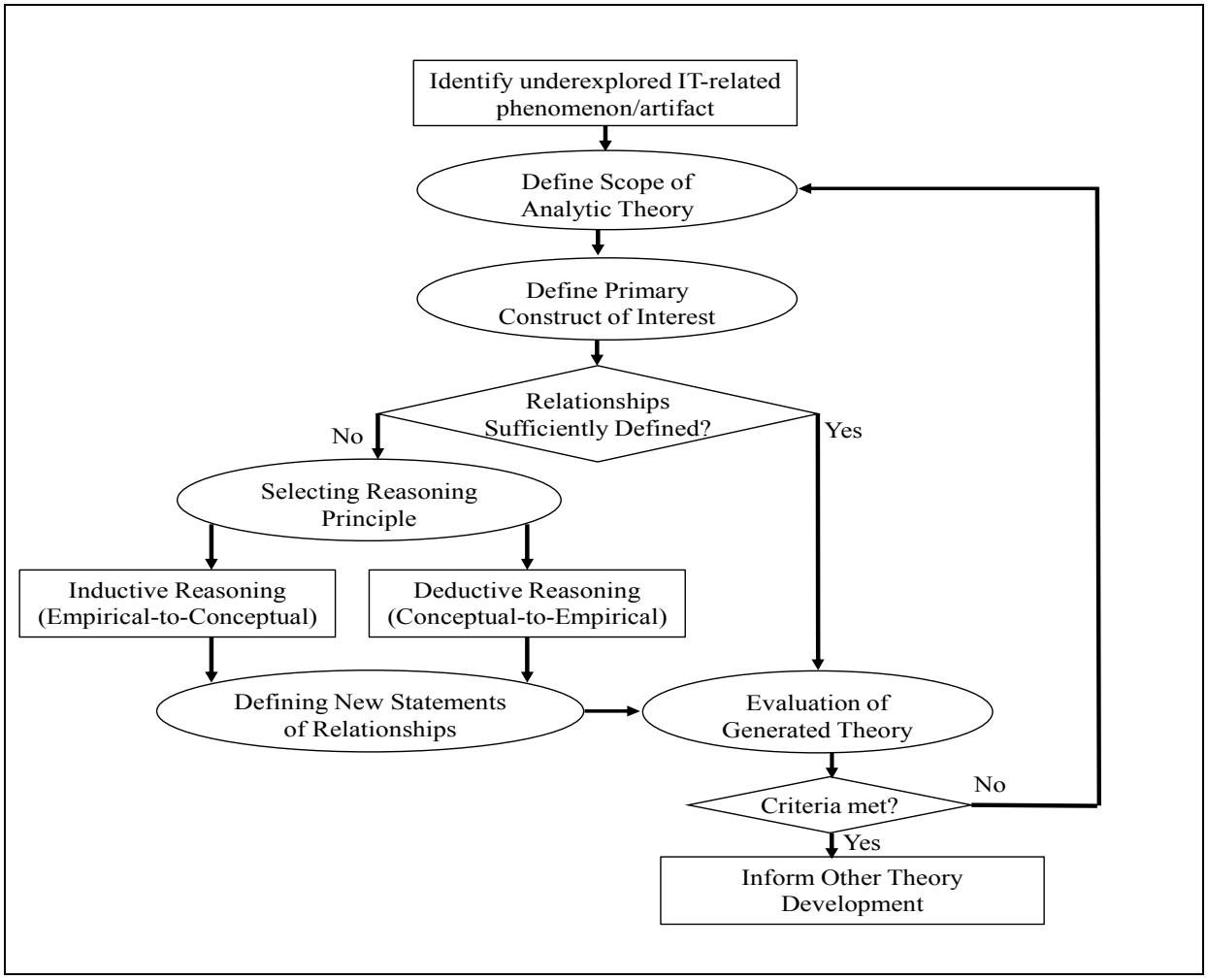

Figure 3. The Process Model for Prescriptive Framework

Mobile Applications Taxonomy as an Analytic Theory

In this section, we address how an existing taxonomy of mobile applications qualifies as a taxonomic theory. The taxonomy is shown in Appendix C. We show that this taxonomy meets the three sufficient conditions for a taxonomic theory given previously, namely that it 1) is represented by a taxonomy meeting our definition and satisfying four evaluation criteria for a taxonomy, 2) includes the components of Table 1 in a way that completely describes the theory and 3) provides a foundation for developing other theories.

The **first condition** is satisfied by expressing the taxonomy in the following taxonomic formula:

T = {Temporal (Synchronous, Asynchronous), Communication (Informational, Reporting, Interactive), Transaction (Transactional, Non-transactional), Access (Public, Private), Multiplicity (Individual, Group), Location (Location-based, Non-location-based), Identity (Identity-based, Non-identity-based)}.

In addition, this taxonomy satisfies the four evaluation criteria as follows:

1. Usefulness: By using a meta-characteristic, meaningful categories and groupings have been defined. The taxonomy is useful in analyzing the existing objects and in identifying applications/objects that can be developed in future to fill gaps in the taxonomy.

2. Clarity of Classification: The taxonomy includes simple and clear rules for classification. The characteristics in each dimension are mutually exclusive.

3. Completeness and Exhaustiveness: Using literature surveys and empirical/inductive and conceptual/deductive approaches, all important categories are identified and included in the taxonomy.

4. Expandability: Due to the reliance on both empirical/inductive and conceptual/deductive approaches, it is easy to include both new entities and ideal types as these are identified in future. The taxonomy can be expanded and evaluated in the future by (a) identifying new classes of mobile applications, (b) new characteristics with expanded knowledge of mobile applications, (c) by utilizing focused group, expert interviews, and/or field study.

The **second condition** is satisfied by the following components of an analytical theory:

Theory Component 1-Means of Representation: Taxonomic formula

Theory Component 2- Primary Constructs: Mobile applications and mobile services

Theory Component 3-Statement of Relationship: A mobile application belongs to a characteristics or dimension.

Theory Component 4-Scope: The set of mobile applications that have been proposed in the scholarly literature and have the stated relationship from TC3 (can be expanded as more applications become available).

The **third condition** is satisfied as follows: The dimensions of the taxonomy can evolve into different constructs for a new theory (such as a theory for mobile applications). This could lead to some "testable propositions" such as "Adding location-awareness will improve the usefulness of mobile applications" or "Group-oriented mobile applications will reduce the quality of service in limited resource environment". We expect that as mobile research progresses, researchers will undertake extension of this taxonomic theory to more comprehensive explanatory and predictive theories. These can further lead to development of "higher-level" theories about mobile applications. These theories will significantly improve our understanding of numerous mobile applications that are available and rapidly emerging.

Because the mobile application taxonomy satisfies the three sufficient conditions, we conclude that it forms a taxonomic theory. A judgment as to the degree to which the theory satisfies these conditions allows one to assess the contribution to knowledge (Gregor 2006).

Discussion & Conclusions

Developing IS theories has been an important goal for many IS researchers. Towards that end, in this paper, we discuss how taxonomic theory can be developed. To address this, we presented a prescriptive framework for taxonomic theory which includes necessary and sufficient conditions and a process model. The prescriptive framework contributes to developing the components of theory for analyzing. In addition, we show how the development of taxonomic theory helps to analyze IS-related phenomena and how it can form the basis for more comprehensive IS-related explanatory, predictive or design theories.

We showed how an existing taxonomy of mobile applications meets the necessary and sufficient conditions to be considered a taxonomic theory. We also evaluated the taxonomy for four criteria of usefulness, clarity of classification, completeness and exhaustiveness, and expandability. The taxonomic theory developed here can be considered as micro-theory (Weber 2012) due to its boundary conditions covering only mobile applications. As the scope of the theory is expanded, the taxonomic theory can lead to higher or macro-level theories.

The more general contributions of this paper are (a) showing when and how taxonomies can lead to taxonomic theories, (b) illustrating how to develop taxonomic theory in the context of IS-related phenomenon (IT artifacts such as mobile applications) and (c) showing how taxonomic theory can provide the basis for future theory development that brings the IT artifact to the core of our research.

The work presented here can also be applied to developing theories in other fields. Taxonomic theories with a focus on the core of our discipline (i.e. the IT artifact) can be expanded to explanatory or predictive theories as the phenomenon of interest becomes more stable and can be studied using more traditional research methods. The prescriptive framework presented in this paper can be used by other researchers in developing taxonomic theories, especially for emerging areas of IT/IS research.

REFERENCES

Bailey, K. D. 1984. "A Three-level Measurement Model," *Quality and Quantity: International Journal of Methodology* (18:3), pp. 225-245.

Bailey, K. D. 1994. *Typologies and Taxonomies - An Introduction to Classification Techniques*, Thousand Oaks, CA: Sage.

Doty D. H. and Glick W. H. 1994. "Typologies as a Unique Form of Theory Building: Toward Improved Understanding and Modeling," *Academy of Management Review (*19:2), pp. 230-251.

Dubin, R. 1978. Theory Building, (Rev. ed.). New York: Free Press.

Eldredge, N. and Cracraft, J. 1980. *Phylogenetic Patterns and the Evolutionary Process*, New York, NY: Columbia University Press.

Glass, R. L. and Vessey, I. 1995. "Contemporary Application-domain Taxonomies," *IEEE Software* (12:4), pp. 63-76.

Gregor, S. 2006. "The Nature of Theory in Information Systems," *MIS Quarterly* (30:3), pp. 611-642.

Gregor, S. and Hevner, A. R. 2013. "Positioning and Presenting Design Science Research for Maximum Impact," *MIS Quarterly* (37:2), pp. 337-356.

Hasselbring, W. 1999. "On Defining Computer Science Terminology," *Communication of the ACM (*42:2), pp. 88-91.

McKnight, D. H. and Chervany, N. L. 2001. "What Trust Means in E-commerce Customer Relationships: An Interdisciplinary Conceptual Typology," *International Journal of Electronic Commerce* (6:2), pp. 35–59.

Moffitt, T. 1993. "Adolescence-Limited and Life-Course Persistent Antisocial Behavior: A Developmental Taxonomy," *Psychological Review* (100:4), pp. 674-701.

Nickerson, R. C., Varshney, U. and Muntermann, J. 2013. "A Method for Taxonomy Development and its Application in Information Systems," *European Journal of Information Systems* (22:3) pp. 336–359.

Orlikowski, W.J., and 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), pp. 121-134.

Reynolds, P.D. 1971. A Primer in Theory Construction. Indianapolis: Bobbs-Merrill.

Saxton, G. D., Oh, O. and Kishore, R. 2013. "Rules of Crowdsourcing: Models, Issues and Systems of Control," *Information Systems Management* (30:1) pp. 2-20.

Shepherd, D.A., and Sutcliffe, K.M. 2011. "Inductive Top-Down Theorizing: A Source of New Theories of Organization," Academy of Management Review (36:2), April 1, 2011, pp 361-380.

Sokal, R. R. and Sneath, P. H. A. 1963. *Principles of Numerical Taxonomy,* San Francisco, CA: W. H. Freeman and Company.

Varshney, U. 2011. *Pervasive Healthcare Computing: EMR/EHR, Wireless and Health Monitoring*, New York City, NY: Springer.

Weber, R. 2003. "Still Desperately Seeking the IT Artifact," *MIS Quarterly* (27:2), pp. iii-xi.

Weber, R. 2012. "Evaluating and Developing Theories in the Information Systems Discipline," *Journal of the Association for Information Systems* (13:1), pp. 2-30.

Whetten, D. A. 1989. "What Constitutes a Theoretical Contribution", *Academy of Management Review* (14:4), pp. 490-495.

APPENDIX A

ANALYSIS OF TAXONOMY PAPERS

Paper (Journal-First Author)	Structural Components of the Analytic Theory				Foundation for developing theories	Evaluation of Produced Taxonomy
	Means of Representation	Primary Constructs	Statement of Relationship	Scope		
ISR-Bryn	Words and subsections	Drivers of product sales	Drivers are technological or non-technological	Multiple drivers are identified by the authors and then classified	None	No formal evaluation of very ad-hoc unstructured taxonomy
JMIS-Aron	Words and Table	Risks associated with outsourcing (strategic risks, operational risks, intrinsic risks of atrophy, and intrinsic risks of location)	Four categories of risks	Multiple risks associate with outsourcing are identified and classified	None	No informal or formal evaluation of simple taxonomy
JMIS-Earl	Words and Tables	Strategies for Knowledge Management	The strategies (not mutually exclusive) are classified in three categories (technocratic, economic and behavioral) and has 7 attributes	Various strategies are identified from multiple primary and secondary sources	None	Informal (discussion of usefulness for decision makers)
JMIS-Irani	Words and Tables	Benefits of MRPII at strategic, tactical, operational levels. Indirect costs of MRPII.	Benefits are financial, non-financial, or partially or totally intangible. Indirect costs are indirect human costs or indirect organizational costs.	Benefits and costs derived from case study of one organization implementing MRPII	Taxonomies are used to evaluate success of implementation of MRPII systems	No formal evaluation of Taxonomies
JMIS-Larsen	Words, tables, diagrams (Good example of taxonomy development)	IS success antecedents (ISSA)	12 categories (dimensions) derived from cluster analysis	ISSAs derived from literature survey	Several possible uses of taxonomy are proposed that could lead to theory development.	Comparison with another taxonomy
JMIS-PK	Words, tables (Very through development of taxonomy using clustering)	Info processing needs, info processing capabilities for products procured through inter-organizational supply chain systems	3 x 2 T derived from Each cell identifies products with common information processing needs and requiring common info processing capabilities	Direct and indirect materials in manufacturing industries	Some suggestions for future research could lead to theory development	No formal evaluation (detailed discussion of usefulness and completeness)
JMIS-Spangler	Computer generated displays	"Themes" specified by researcher	Based on common themes in documents	Documents	None given	Using statistical techniques
JMIS-Zhou	Words and diagrams of hierarchical taxonomy (experimental data to derive a	Cues to error detection (CERD) in speech recognition software	CERDs had hierarchical relationships	Speech recognition errors identified by 10 participants in experiment	States that T can be used to investigate CERD in a systematic way" which could imply that it could be used for CERD	Not formally

	taxonomy)				theory development	
MISQ-Bapna	Word and Tables	Bidding strategies in online auctions	The classified objects in a cluster share bidding strategy	Set of bidding actions (1999 and 2000) from online auction data	Two taxonomies are used for hypothesis testing	Not formally (but usefulness and completeness are implied)
MISQ-Earl	Words and Tables	Strategic Information Systems Planning (SISP) Approaches	One approach per classification (five approaches identified)	Approaches identified from the literature and interviews of executives	Future theory development is mentioned, but no attempts to develop theory are made	Not formally (but derived based on interview data, appears to be comprehensive and expandable)
MISQ-McKinney	Words and Tables	Views of Information (Token, Syntax, Representation and Adaptation)	Each dimension represents one view of information with 8 characteristics	Using literature (4 MIS journals), different views are identified and classified	Not an explicit goal (but possibly a future direction)	No formal evaluation (normative or idealized taxonomy, likely to be useful and comprehensive)
MISQ-Nambisan	Words and Tables	Organizational Mechanisms for IT innovation	Organizational mechanisms are classified based on 5 classes (literature)	Organizational mechanisms are organized in 4 classes using Delphi and Field Study	Some theory development using mechanisms as independent and IT innovation as dependent variable	No formal evaluation of taxonomy (appears to be useful but not comprehensive)
MISQ-Posey	Words and Diagrams	Protection-Motivated Behaviors	8 categories, where two PMBs share characteristic	67 identified PMBs (from interviews) are classified	Theory development is not addressed (possibly a future activity)	No formal evaluation of taxonomy (appears to be comprehensive and clearly defined)
MISQ-Son	Words and Diagrams	Information Privacy-Protective Responses (IPPR)	3 categories are identified	6 types of IPPR responses are classified	Some theoretical basis is provided for different responses (but no attempts to move taxonomy towards a theory)	No formal evaluation of taxonomy (appears to be comprehensive)
MISQ-Suzanne	Words and Tables	IT Implementers' response to user resistance	Four categories identified based on survey of cases	The available responses to user resistance	Taxonomy is a classification derived from the literature, but the goal is not theory development	No formal evaluation of taxonomy (but it appears to be useful and complete)
MISQ-Zhang	Words and Tables	Affective Concepts	Concepts within a category share certain similarity	Affective Concepts identified from Literature (psychology and ICT)	Taxonomy is used to support some hypothesis, but taxonomy as a theory is not the focus	No formal evaluation of taxonomy as theory (appears to be useful and comprehensive)

**: A methods paper on IS theories on "how to" develop type I theory, but not developing a taxonomy and evaluating it.

Table A1: Literature Survey of Taxonomy Papers in Major MIS Journals

APPENDIX B

TAXONOMY DEVELOPMENT METHOD

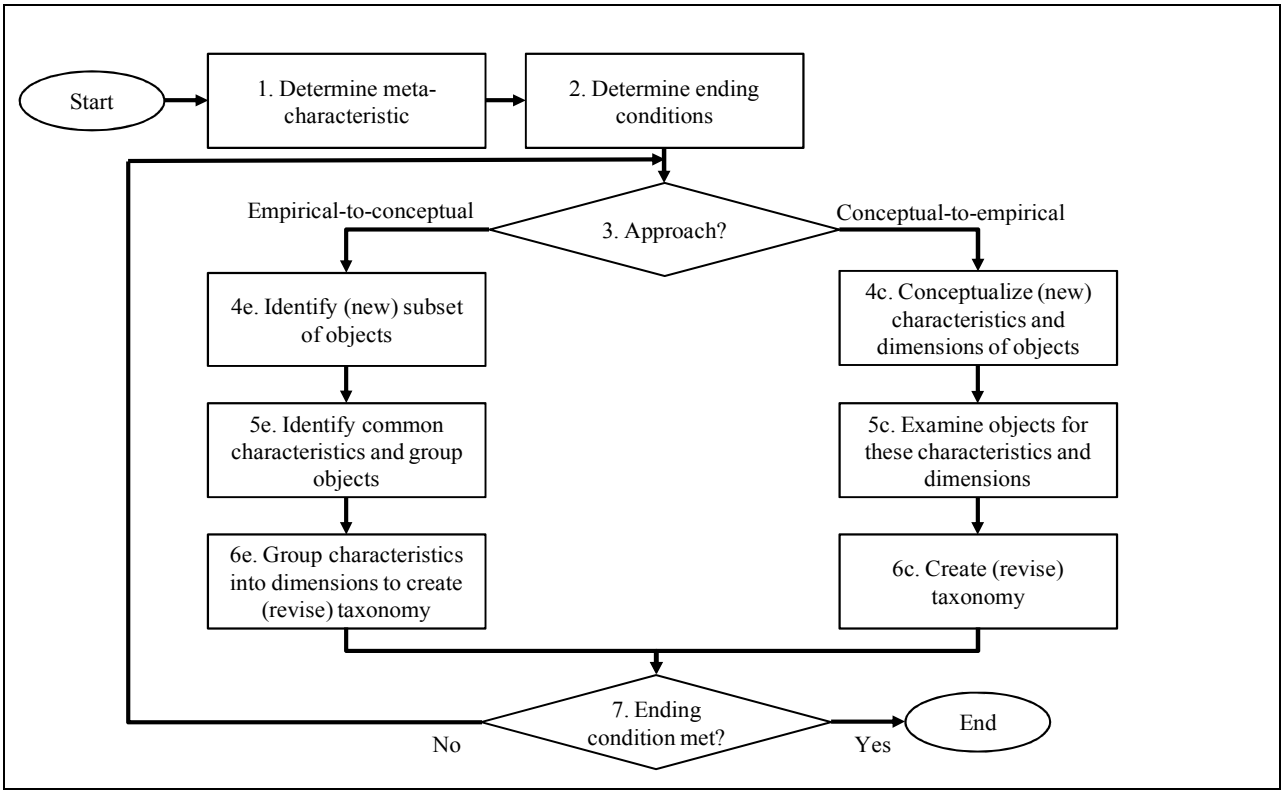

Figure A1. The Taxonomy Development Method

APPENDIX C

TAXONOMY FOR MOBILE APPLICATIONS

The taxonomy can be described by the following taxonomic formula:

T = {Temporal (Synchronous, Asynchronous), Communication (Informational, Reporting, Interactive), Transaction (Transactional, Non-transactional), Access (Public, Private), Multiplicity (Individual, Group), Location (Location-based, Non-location-based), Identity (Identity-based, Non-identity-based)}.

Table A2 shows the application of this taxonomy to classify certain types of mobile applications.

	Temporal		Communication			Transaction		Access		Multiplicity		Location		Identity	
Applications	S	AS	INF	RP	INT	T	NT	PU	PR	I	G	LB	NLB	I	NI
Mobile voice communications	X				X		X	X		X			X	X	
Mobile messaging		X	X				X	X		X			X	X	
Mobile TV	X		X				X	X		X			X		X
Purchasing location-based contents	X		X			X		X		X		X		X	
Mobile inventory management		X		X			X		X	X		X		X	
Product location and tracking		X	X				X	X		X		X			X
Mobile advertisement		X	X				X	X		X		X			X
Mobile navigation	X		X				X	X		X		X			X
Mobile games	X				X	X		X			X		X	X	
Mobile entertainment services	X		X			X		X		X		X			X
Mobile social networking		X			X		X		X		X		X	X	
Mobile communities		X			X		X	X			X		X		X
Mobile auctions and financial services		X			X	X		X			X		X	X	
Mobile distance education	X				X		X	X		X			X	X	
Mobile ticketing		X			X	X		X		X			X		X

Table A2: Mobile Taxonomy