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# Taxonomy Development in Information Systems: A Literature Survey and Problem Statement

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**ABSTRACT**

The complexity of the information systems field often lends itself to classification schemes, or taxonomies, which provide ways to understand the similarities and differences among objects under study. Developing a taxonomy, however, is a complex process that is often done in an ad hoc way. This research-in-progress paper surveys 65 papers in information systems, computer science, and business to identify methods used for taxonomy development. Our analysis of this survey indicates that there is considerable interest in taxonomies, but formal development procedures are not always used. We conclude that such a procedure would be beneficial for the information systems discipline, and we present a problem statement for defining a procedure. We also describe our current research on this problem, which we hope will lead to an approach for the systematic development of taxonomies. As both taxonomies (i.e., models) and taxonomy development procedures (i.e., methods) represent artifacts, this paper serves to illustrate an analysis that provides a foundation for applying the design science research paradigm and to theorize about IT artifacts observed (i.e., instantiations).

**Keywords**

Taxonomy, taxonomy development, research methodologies

## INTRODUCTION

A fundamental problem in many disciplines is classifying objects of interest into taxonomies. Biology has studied this problem extensively and developed a number of classification schemes that order the complexity of the living world and provide a foundation for biological research. Classification schemes are also found in many social science fields.

Suitable taxonomies play an important role in research and management because the classification of objects helps researchers and practitioners understand and analyze complex domains. The reduction of complexity and the identification of similarities and differences among objects are major advantages provided by taxonomies (Bailey 1994). Furthermore, taxonomies enable researchers to study the relationships among objects and, therefore, to hypothesize about these relationships. As a vocabulary of a domain and as a set of defined constructs, taxonomies can add to a discipline's knowledge base and therefore lay the basis for future research approaches (Hevner, March and Park 2004; March and Smith 1995). As illustrated by Williams, Chatterjee and Rossi (2008), taxonomies can furthermore be useful in understanding the science behind design principles of artifacts observed. Orlikowski and Iacono (2001) stress the need for theorizing about IT artifacts in the IS discipline.

In the information systems field the importance of taxonomies is well recognized. As we demonstrate later in this paper, a number of taxonomies have been proposed in information systems. These taxonomies can provide fundamental research foundations in the form of a common domain language in which problems and their solutions are defined and explored.

Although the process of developing a taxonomy has been studied in a number of disciplines (e.g., Eldredge and Cracraft 1980 and Sokal and Sneath 1963 in biology; Bailey 1994 in the social sciences), little has been written about this process in the information systems field. A well-conceived method for developing taxonomies in information systems would serve as a basis for developing new taxonomies that could bring order to complex areas and potentially lead to new research directions. Our long-range research goal is to define such a procedure.

Before defining a taxonomy development procedure, we need to examine how taxonomies are developed by other researchers in information systems. The purpose of this research-in-progress paper is to survey a range of information systems literature in order to identify common themes related to taxonomies and taxonomy development. A further purpose of this paper is to define clearly the problem of taxonomy development in information systems to serve as a basis for the next phase of our research.

A taxonomy development procedure is an artifact (method) that can be built and evaluated following the design science paradigm (March and Smith 1995). The result of applying the method is also an artifact (model) that itself can be evaluated. Although we do not complete the process of building these artifacts in this paper, we lay the foundation for doing so in future research.

This paper is organized as follows. The next section discusses taxonomy development in other disciplines. In the following section we present our literature survey and our analysis of the papers surveyed. Then in the next section we give our problem statement for defining a taxonomy development procedure in the information systems field. We conclude the paper in the last section and explain our current and future research.

## TAXONOMY DEVELOPMENT IN OTHER DISCIPLINES

Before proceeding to our literature survey, we need to gain an understanding of the process of taxonomy development in general by examining how other established disciplines approach the problem.

Perhaps the taxonomy best known to most people is that of living organisms from biology. Biology textbooks usually present the traditional Linnaean taxonomy, which classifies organisms based on a predefined hierarchy of categories from kingdom to species. Determining where a new organism falls in the taxonomy involves identifying into which classification the organism fits at each level of the hierarchy.

Biological taxonomy development is not limited to the traditional approach, however. Taxonomists also use phenetics and cladistics. *Phenetics*, also called numerical taxonomy, involves classifying organisms solely on the basis of their similarity. The researcher identifies different characteristics of organisms and then uses statistical techniques to clusters the organisms into similar groups based on these characteristics (Sokal and Sneath 1963). In contrast, c*ladistics* does not look at common characteristics but rather examines the evolutionary relationships among organisms (Eldredge and Cracraft 1980). The researcher investigates the evolution of organisms from others and then groups organisms based on their evolutionary heritage. Two organisms may be closely related in a cladistic taxonomy because they have a common ancestor even though they do not share certain characteristics, thus putting them in different groups in a phenetic analysis.

Taxonomy development in the social sciences has also been well studied. Bailey (1994) provides a thorough survey of the subject. Bailey distinguishes between a typology and a taxonomy, saying that the former is derived conceptually or deductively and the latter is derived empirically or inductively. In the conceptual typology approach, the researcher proposes a typology of categories or *types* based on a theoretical ideal or model. In the process the researcher could define an *ideal type*, which Bailey (citing Weber 1949) explains is the "extreme" or "nirvana" of types. The ideal type is used to examine empirical cases in terms of how much they deviate from the ideal. Alternatively, in the empirical approach the researcher proposes a taxonomy based on a *constructed type*, which, as Bailey (citing McKinney 1966) explains, is not the ideal but based on reference to empirical cases. The constructed type is used to examine "exceptions" to the type. Bailey compares the ideal type to the highest value in a set of data (assuming highest is best) and the constructed type to the mean of the data (Bailey 1994, 23).

In the conceptual approach the researcher develops a typology starting with a conceptual or theoretical foundation and then derives the typological structure through deduction. The researcher may conceive of a single type and then add dimensions until a satisfactorily complete typology is reached, a process called substruction (Bailey 1994, 24). Alternatively, the researcher could conceptualize an extensive typology and then eliminate certain dimension in a process called reduction (Bailey 1994, 24) until a sufficiently parsimonious typology is reached.

The conceptual approach is not based on empirical data, although such data could be brought in toward the end of the process for verification purposes. The empirical approach, on the other hand, starts with data and derives the classification from this data using cluster analysis or other statistical methods (Bailey 1994, 34). The goal is to find similarities among the data and to classify similar objects into the same category. Each category in the resulting taxonomy is called a *taxon* (plural *taxa*). Using the concepts from biology, this approach is phenetic.

## SURVEY OF TAXONOMY DEVELOPMENT PAPERS

In order to examine taxonomy development in information systems, we surveyed 65 papers that proposed new taxonomies in the information system, computer science, and business fields. We focused on information systems papers (44) but because we want to see how taxonomies are developed in closely related fields we also examined some papers proposing taxonomies in computer science (10) and in non-information systems business disciplines (11). All papers surveyed are listed later in this paper. We classified each paper by its principal domain: information systems (IS), computer science (CS), and non-IS business (Bus). We recognize that the line between IS and CS is sometimes not clear. For borderline cases, we classified a paper as IS if it emphasized the organizational/managerial aspects of the topic and as CS if it emphasized the technical aspects. Papers in e-commerce were classified as IS as were papers in mobile commerce. Non-IS business papers include papers in marketing, manufacturing, management, and other areas of business.

For each paper we noted the type of taxonomy it developed and the approach or method that the authors used for developing its taxonomy. We classified the approach into one of the following categories:

- Inductive
- Deductive
- Intuitive

The inductive approach involves observing empirical cases which are then analyzed to determine dimensions and characteristics in the taxonomy. The analysis may be done using statistical techniques such as cluster analysis or may use less rigorous techniques; we noted this in our survey. This methodology is called phenetics or numerical taxonomy in biology. Bailey (1994) calls this the empirical approach in sociology.

The deductive approach derives a taxonomy not from empirical cases but instead from theory or conceptualization. It identifies dimensions and characteristics in the taxonomy by a logical process derived from a sound conceptual or theoretical foundation. Cladistics in biology uses this approach. In sociology, Bailey (1994) identifies this as the conceptual approach. This approach may be followed by an analysis of empirical cases to evaluate and perhaps modify the taxonomy.

The intuitive approach is essentially ad hoc. The researcher uses his or her understanding of the objects to be classified to propose a taxonomy based on the researcher's perceptions of what makes sense. There is no formal method in this approach.

Table 2 at the end of this paper lists the papers that we surveyed and our classifications of these papers.

We make the following observations from our reading of these papers and the data in Table 2:

1. Many papers have "taxonomy" in their titles. This implies to us that there is interest in taxonomies in the information systems field and that researchers find taxonomies useful.
2. There appears, however, to be a great deal of confusion about what a taxonomy is. Some authors seem to use the word taxonomy to show that they are aware of the literature related to their problem area. They classify the literature into two or three simple categories, which may not completely define their domain.
3. Some authors create simple NxN (N=2, 3, 4) classifications with limited possibilities to fit the majority of objects. Other authors present lists as taxonomies, including lists of functions someone has to perform.
4. Most papers use taxonomies with 4 or fewer dimensions. A few papers present taxonomies with more than ten dimensions.
5. Many papers provide little information about the method the authors used to develop their taxonomies (the column labelled "Approach identified in paper" in Table 2). In fact, we classified a little over one third (24) of the surveyed papers as not identifying the method used. In some cases we were able to infer the method from other comments in the paper. When we could not, we interpreted these papers as using a purely intuitive approach based on the author's perception of what is a good classification and how it can cover the majority of objects. We recognize that our interpretation may be incorrect in some instances. Several other papers were classified as using an intuitive approach. In total we classified 25 papers as using an intuitive approach.
6. Many papers do not base their taxonomy on a conceptual, theoretical, or empirical foundation. Although authors review the literature in their problem area, their taxonomy is often not based on their literature review, but instead is ad hoc. We classified these as using an intuitive approach.
7. Of the papers that use an inductive approach (24) about half (11) use formal statistical analysis to identify clusters appropriate for their taxonomy. The other papers (13) use informal techniques to examine their empirical cases.
8. Papers that use a deductive approach (13) were hard to identify. Some of the papers that we identified as using an intuitive approach may, in fact, use a deductive approach.
9. Table 1 (next page) shows the distribution of approaches used in IS, CS, and business papers. We note that papers in business tend to be more formal in their approach whereas papers in CS and IS tend to be less formal. Papers in the IS domain use the most diverse taxonomy development approaches.
10. Few papers cite the taxonomy development literature from other disciplines that we have identified.

A general conclusion from these observations is that taxonomies are useful in information systems and that a formal taxonomy development procedure that others can use in their research would benefit the discipline.

| Principal domain | Taxonomy development approach | | | | |
|---|---|---|---|---|---|
| | Inductive (statistical analysis) | Inductive (informal analysis) | Deductive (may be followed by empirical verification) | Intuitive | Other |
| IS | 6 | 11 | 8 | 17 | 2 |
| CS | | 2 | 1 | 7 | |
| Bus | 5 | | 4 | 1 | 1 |
| Total | 11 | 13 | 13 | 25 | 3 |

**Table 1. Taxonomy development in different domains**

## PROBLEM STATEMENT FOR TAXONOMY DEVELOPMENT IN INFORMATION SYSTEMS

In this section we state the research problem that we are exploring, that of defining a procedure for taxonomy development in information systems. We choose to use the term taxonomy because it is more common and recognizable than the term typology, although we recognize that the latter may be more correct in some situations.

To start we define what we mean by a taxonomy. A taxonomy T is a set of n dimensions $D_i$ (i=1, … , n) each consisting of $k_i$ ($k_i \geq 2$) mutually exclusive and collectively exhaustive characteristics $C_{ij}$ (j=1, … , $k_i$) such that each object under consideration has one and only one $C_{ij}$ for each $D_i$. Stated another way,

$$T = \{D_i, i = 1, \dots, n \mid D_i = \{C_{ij}, j = 1, \dots, k_i, k_i \geq 2\}\}$$

The mutual exclusive restriction means that no object can have two different characteristics in a dimension. The collectively exhaustive restriction means that each object must have one of the characteristics in a dimension. Together these conditions mean that each object has exactly one of the characteristics in each dimension.

We want to develop useful taxonomies, but not necessarily “best” or “correct” ones, as these cannot be defined and, in fact, may be moving targets that could change over time as information systems evolve. The taxonomy development literature gives us little help with metrics for evaluating taxonomies. Indeed, Bailey (1994, p. 2) makes this clear when he repeatedly asks which of his example classifications is “best” without giving guidance for finding the answer other than saying that “a classification is no better than the dimensions or variables on which it is based.” Later he lists “weaknesses” of typologies including lack of mutual exclusivity and collective exhaustivity; lack of parsimony; lack of changeability (i.e., they are static); based on criteria that are arbitrary or ad hoc; and descriptive rather than explanatory (Bailey 1994, 34). We note that we found these weaknesses in some of the proposed taxonomies surveyed previously.

Without guidance from the literature we are left on our own to define a useful taxonomy. We proposed that a useful taxonomy has the following attributes:

- It is concise. It contains a limited number of dimensions and a limited number of characteristics in each dimension, because an extensive classification scheme with many dimensions and many characteristics would be difficult to comprehend and difficult to apply. Put another way, it is parsimonious.
- It is sufficiently inclusive. It contains enough dimensions and characteristics to be of interest. For example, a taxonomy with only one dimension and two characteristics within that dimension would not be very interesting. This attribute can conflict with the conciseness attribute.
- It is comprehensive. It provides for classification of all current objects within the domain under consideration.
- It is extendible. It allows for inclusion of additional dimensions and new characteristics within a dimension when new types of objects appear. Put another way, it is dynamic, not static.
- It is explanatory. It contains dimensions and characteristics that do not describe objects but, rather, provide useful explanations of the nature of the objects under study or of future objects.

A taxonomy development procedure should have certain qualities. The goal of such a procedure is to develop a taxonomy with a set of dimensions each consisting of a set of characteristics that sufficiently describes the objects in a specific domain of the information systems field. The procedure should have the following qualities:

- It takes into consideration alternative approaches to taxonomy development. Because several approaches to taxonomy development are used, and no single approach has been determined to be “best”, any procedure must be flexible enough to allow for the selection of an approach or combination of approaches that is appropriate for the domain being studied.

- It reduces the possibility of including arbitrary or ad hoc dimensions and characteristics in the taxonomy. Any taxonomy should have dimensions and characteristics based on solid conceptual or empirical grounds. Arbitrary or ad hoc dimensions and characteristics should be avoided and the taxonomy development procedure must support this goal.
- It can be completed in a reasonable period of time. Any procedure must have a way of determining when it is finished. There must be an ending condition in the taxonomy development procedure that says when to stop and this ending condition must be reachable in a reasonable amount of time.
- It must be straightforward to apply. Because taxonomies are developed by researchers with different levels of understanding of the taxonomy development literature, any procedure must be relatively easy to understood and apply.
- It must lead to a useful taxonomy as defined above. Since our goal is to develop useful taxonomies, any procedure must accomplish this goal.

Our problem statement can thus be stated as follows: Define a procedure for developing taxonomies in information systems such that

- The resulting taxonomies satisfy the definition of a taxonomy given previously.
- The resulting taxonomies have the attributes listed previously.
- The procedure has the qualities listed previously.

## SUMMARY AND CONCLUSION

This research-in-progress paper presents a survey of IS, CS, and business papers that show taxonomies in various domains. Our analysis of the survey indicates that there is considerable interest in taxonomies in information systems, but a formal procedure for developing taxonomies is not always used. We conclude that such a procedure would be beneficial for the information systems field and present a problem statement for defining a procedure. We propose to define an information system taxonomy development procedure with certain qualities that results in taxonomies that meet our formal definition of a taxonomy and that have certain desirable attributes.

Our research into defining such a procedure has already begun. We have proposed a preliminary procedure and used it to develop a taxonomy of mobile applications (Nickerson et al. 2009). We are currently working on refining and revising this procedure based on the further understanding gained from the survey in this paper and other investigations we have undertaken. The refined procedure is iterative and incorporates both inductive and deductive approaches. We anticipate publication of our final procedure in the near future. Other areas of research that we are pursuing include applying the procedure to different IS domains to demonstrate its effectiveness, and then analyzing the resulting taxonomies to identify areas for future research. This would also provide support when theorizing about novel IT artifacts. As pointed out by Venable (2006), design theory should relate to "improvements expected from applying a particular type or types of technologies". A taxonomy development methodology will assist researchers in the process of identifying and classifying such types. We are also interested in applying the procedure to other areas, including CS and non-IS business domains, to test both its generalizability and its usefulness. This work could lead to the development of a framework for taxonomy generation. The framework may also include abstracted principles and suitable metrics to measure effectiveness of generated taxonomies for different domains. Such research results would clearly contribute to the foundations and methodologies of the IS knowledge base (Hevner et al. 2004).

Additional work could include developing taxonomies for certain domains where some work has already been done and then identifying additional work to do. A well-developed taxonomy would be a good starting point for initiating the development of new domain-specific theories.

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| | | | Taxonomy development approach | | | | |
|---|---|---|---|---|---|---|---|
| **Citation** | **Principal domain** | **Approach identified in paper** | **Inductive with statistical analysis** | **Inductive with informal analysis** | **Deductive (may be followed by empirical verification)** | **Intuitive** | **Other** |
| Abdelaal and Ali (2007) | IS | Yes | | X | | | |
| Alter (1977) | IS | Yes | | X | | | |
| Anderson and Jensen (1975) | CS | Yes | | | | X | |
| Ball, Adams, and Xia (2004) | IS | No | | | | X | |
| Beranek and Horan (2006) | IS | Yes | X | | | | |
| Bitton, DeWitt, Hsaio, and Menon (1984) | CS | No | | | | X | |
| Blum (1994) | CS | No | | | | X | |
| Camel and Eisenberg (2006) | IS | Yes | | | | | X |
| Carr and Lu (2007) | IS | Yes | | | X | | |
| Chuang and Chien (2003) | IS | Yes | X | | | | |
| Chung and Chien (2005) | IS | Yes | X | | | | |
| Cotterman and Kumar (1989) | Bus | Yes | | | | | X |
| Denning and Branstad (1996) | CS | No | | | | X | |
| Dobson (2004) | IS | No | | | | X | |
| Dombroviak and Ramnath (2007) | IS | No | | | | X | |
| Durcikova and Everard (2002) | IS | No | | | | X | |
| Earl (2001) | IS | Yes | | X | | | |
| Farbey, Land, and Targett (1995) | IS | Yes | | | X | | |
| Fiedler, Grover, and Teng (1996) | IS | Yes | X | | | | |
| Filley and Aldag (1978) | Bus | Yes | | | X | | |
| Gillenson, Sherrell, and Chen (2000) | IS | Yes | | X | | | |
| Gregg and Scott (2008) | IS | Yes | | | X | | |
| Hambrick (1983) | Bus | Yes | X | | | | |
| Hasan (2009) | IS | Yes | | X | | | |
| Heinonen and Pura (2006) | IS | Yes | | | | X | |
| Irani and Love (2001) | IS | No | | | | X | |
| Kafentzis, Apostolou, and Mentzas (2004) | IS | No | | | | X | |
| Kayworth, Brocato, Whitten (2005) | IS | Yes | | X | | | |
| Kearns (2005) | IS | Yes | | | | | X |

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|---|---|---|---|---|---|---|---|---|
| Kemper and Wolf (2002) | IS | No | | | | X | |
| Landwehr, Bull, McDermott, and Choi (1994) | CS | No | | | | X | |
| Larsen (2003) | IS | Yes | X | | | | |
| Laufer (1968) | Bus | No | | | | X | |
| Leem, Suh, and Kim (2004) | IS | No | | | | X | |
| LeRouge and Gjestland (2002) | IS | No | | | | X | |
| Limonad and Wand (2009) | IS | No | | | X | | |
| Lu and Campbell (2007) | IS | No | | X | | | |
| McKnight and Chervany (2002) | IS | Yes | | | X | | |
| McKnight, Choudhury, and Kacmar (2002) | IS | Yes | | | X | | |
| Merritt (1985) | CS | No | | | | X | |
| Meso and Madex (2000) | IS | Yes | | | | X | |
| Miller and Roth (1994) | Bus | Yes | X | | | | |
| Mistilis and D'Ambra (2007) | IS | Yes | | | X | | |
| Monarchi and Phur (1992) | IS | No | | | | X | |
| Narasipuram (2006) | IS | No | | | | X | |
| Nickerson (1997) | IS | Yes | | | | X | |
| Nickerson, Varshney, Muntermann, and Isaac (2007) | IS | No | | | | X | |
| Olivier and Von Solms (1994) | CS | No | | | | X | |
| Paswan, D'Souza, and Zolfagharian (2009) | Bus | Yes | | | X | | |
| Pearson and Shim (1994) | IS | Yes | X | | | | |
| Pruden (1973) | Bus | Yes | X | | | | |
| Puglisi, Smyth and Turpin (2007) | CS | Yes | | X | | | |
| Robinson and Bennett (1995) | Bus | Yes | X | | | | |
| Sabherwal and King (1995) | IS | Yes | | X | | | |
| Sester and Eder (2006) | IS | Yes | | X | | | |
| Son and Kim (2008) | IS | No | | X | | | |
| Tangpong, Michalisin and Melcher (2008) | Bus | Yes | | | X | | |
| Venugopal, Buyya, and Ramamohanarao (2006) | CS | Yes | | X | | | |
| Vereecke, Van Dierdonck, and De Meyer (2006) | Bus | Yes | X | | | | |
| Wang and Want (2003) | CS | No | | | X | | |
| Ward, Whymark, and Zelmer (2004) | IS | Yes | | X | | | |
| Williams and Ramaprasad (1996) | Bus | Yes | | | X | | |
| Williams, Chatterjee, and Rossi (2008) | IS | Yes | | | | X | |

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|---|---|---|---|---|---|---|---|---|
| Yoshioka, Herman, Yates, and Orlikowski (2001) | IS | Yes | | | X | | |
| Zeimpekis, Giaglis, and Lekakos (2003) | IS | No | | | | X | |

**Table 2. Summary of Papers Surveyed**