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Accumulating IS Theories Using a Network Approach Towards Meta-Analysis

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ACCUMULATING IS THEORIES USING A NETWORK APPROACH TOWARDS META-ANALYSIS

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Abstract

The adoption and usage of new information and communication technologies (ICT) have been investigated from different theoretical points of view, such as Diffusion of Innovations (DOI; Rogers, 1995) and the Technology Acceptance Model (TAM; Davis, 1989). Numerous empirical studies are available, but systematic reviews that accumulate the results are not abundant.

Meta-analysis is a way to accumulate the results of scientific research. Usually, a meta-analysis study focuses on investigating collected empirical results with regard to a single hypothesis. In this research we take a broader perspective by adding principles of network analysis to the basics of meta-analysis. This encompasses that we consider the concepts (or variables) in the hypotheses of relevant scientific papers and use them as the nodes in a network. Moreover, the presupposed relations between the concepts (also depicted in the hypotheses) are the links between nodes. The concept network that emerges can subsequently be analyzed in terms of e.g. density and degree. In order to test the robustness of a theory we compare the network of theoretically posed relations to the network of relations that are empirically validated and found significant. The paper describes the use of this approach towards meta-analysis as well as a tool that supports the approach: the Open Knowledge Infrastructure (OpenKI). This publicly accessible online database allows storage and retrieval of hypotheses and meta-information of scientific papers.

Keywords: Technology Acceptance Model, Diffusion of innovations, Meta-analysis, Network analysis

1 INTRODUCTION

De Groot (1969) describes the scientific process as a cycle in which theoretical notions are put to an empirical test. In this cycle the results can be used for further development of theoretical notions. In this paper we follow the empirical cycle twice: [1] by testing a method to perform meta-analysis and [2] by accumulating the empirical findings of two theoretical frameworks.

Information and communication technology (ICT) is developing rapidly. With these developments, empirical research meant to understand, explain and predict the processes of adoption and use of new ICT is also expanding. These processes are investigated in several research areas, such as organizational science, communication science and information systems, resulting in theories, approaches and models such as Diffusion of Innovations (DOI; Rogers, 1962; 1995), Theory of Reasoned Action (Ajzen and Fishbein, 1980), the Technology Acceptance Model (TAM; Davis, 1989), Domestication (Silverstone and Haddon, 1996), Social Exchange Theory (Homans, 1958) and Task Technology Fit (Goodhue, 1995). These theoretical insights, especially those of TAM and DOI, have often been tested in quantitative empirical research. As a result a substantial number of empirical studies with regard to the adoption and use of ICT is available.

In their article on literature reviews the Information Systems (IS) field, Webster and Watson (2002) state that there are only few published review articles. As a result of that the progress of the IS field is impeded. A well known way to study and accumulate empirical results is meta-analysis. According to Light and Pillemer (1984), traditional literature reviews are subjective, scientifically unsound and not efficient. They state that meta-analyses are more rigorous and systematic. Meta-analysis encompasses all of the methods and techniques of quantitative research synthesis (Lipsey and Wilson, 2001; Hedges and Olkin, 1985; Lewis and Grimes, 1999). Since empirical research on the adoption of new technology is growing fast and since many of these studies are based on explicit theories and hypothesis, we argue that it is possible to perform a rigorous meta-analysis on this matter.

Although not abundant, there have been several meta-analyses in IS (Tornatzky and Klein, 1982; Alavi and Joachimsthaler, 1992; Benbasat and Lim, 1993; Hwang, 1996; Mahmood, Hall and Swanberg, 2001; Ma and Liu, 2004; Sultan, Farley and Lehmann, 1990; Yousafzai, Pallister and Foxall, 2006). Most of these papers, take one theory, a small amount of concepts or a single hypothesis into account. In contrast, Venkatesh, Morris, Davis, and Davis (2003) take as many as eight models into account. They use the core constructs from the models and empirically test them in four field studies. Although Venkatesh et al. provide a meaningful study, they lack a systematic method to identify the constructs that form the basis of their Unified Model of Technology Acceptance (UTAUT). In this paper we do provide a systematic and controllable approach towards accumulating the results of (quantitative) empirical research papers using the hypotheses that are posed and tested in scientific papers. This brings us to the basic assumption of this research which is that the hypotheses that are posed and tested are central in scientific research. The reason for this assumption is that we define a theory as a coherent system of hypotheses. A hypothesis in turn suggests a possible correlation between two concepts.

By analyzing the hypotheses that are posed and empirically tested we will obtain an overview of all the concepts that are relevant to a theoretical framework. Next to that, we will accumulate the results from the different papers in terms of a (social) network (Wasserman and Faust, 1994; Hanneman and Riddle, 2005) in which concepts are the nodes and the hypotheses are the links that connect the nodes. In order to do that we will make use of a the Open Knowledge Infrastructure (OpenKI) tool that we developed and used in this study. Because the use of this tool and a network analysis approach towards meta-analysis is new, the first research question is:

RQ1 *What are the possibilities and limitations of performing meta-analysis with the aid of the OpenKI tool and network analysis?*

The second aim of this research is to gain insight into the concept network for two widely accepted theories in the IS field, being Diffusion of Innovations and the Technology Acceptance Model. Accordingly, the second research question is:

RQ2 Which key theoretical concepts on the adoption and use of new technologies can be identified and how do these concepts relate to each other in a network of concepts?

Ultimately, the results of this research can provide us with a deeper understanding of how the two theoretical frameworks (DOI and TAM) can help us understand the diffusion of ICT. Although this way of performing literature research can be applied to the whole domain as well as any sub domain of the adoption and use of IS systems, this study emerged from a project on residential broadband adoption and usage in the Netherlands (see Vermaas, 2007). Therefore we selected papers from this sub domain.

An important aspect of quantitative scientific research is the empirical validation of hypotheses that are posed. Researchers examine, by operationalization of concepts, gathering data and (statistical) data analysis, if and to what degree a theoretical proposition can be validated in the empirical world. In general terms, validation is described as the success with which the measure obtained in particular cases allows us to predict the measures that would be arrived at by other procedures in other contexts (Kaplan, 1973). By comparing the theoretically posed hypotheses to the empirical results (i.e. the hypotheses that were supported) of a number of papers we accumulate the value of a theoretical framework in different contexts. This brings us to the third research question:

RQ3 How are the theoretically posed hypotheses related to the relations that are empirically supported?

In the next section we will describe our approach towards finding answers to the research questions posed above. First of all, we will describe how literature was collected and analyzed. Secondly, we will describe the OpenKI tool that was built to support meta-analysis. After this, we will present the results of our data gathering and analysis. Finally, we will present our conclusions and suggestions for further research.

2 RESEARCH METHOD

For this paper we have performed a meta-analysis that is innovative in two ways. First, it uses a database tool to collect the required data from literature, the OpenKI tool. Secondly, we have used network analysis to map the relations between hypothesized variables and between validated variables. In this section we will provide an overview of the way in which literature was gathered, the OpenKI tool and network analysis.

2.1 Selection of the Literature

In order to select literature for the meta-analysis we used the Association of Information Systems (AIS) community as a starting point. The corresponding website (www.isworld.org), provides an overview of theories and approaches relevant to the IS field. The overview also provides relevant literature. To add to these lists of literature we also looked for relevant literature on Google Scholar (scholar.google.com) and in Omega at Utrecht University in The Netherlands. Omega is a search engine developed at the library of Utrecht University which offers access to almost 15 million digital 'full-text' articles at omega.library.uu.nl As key terms we have used the name of the theory combined with domain specific terms such as ICT, technology, internet and broadband. From the found literature a selection was made, based on the availability of the papers. Schwartz and Russo (2004) conclude their research with the remark that knowledge of which indexes (databases with literature) are best to use is helpful to researchers, but that access to the indexes might be a problem. To some papers indeed, we were not able to get access, in spite of the various licenses Utrecht University has for

scientific journals. After this step of retrieving literature the appropriateness of the papers were estimated by reading abstracts. The main condition was that it had to be empirical research, based on TAM or DOI and that the subject was new information and/or communication technology (which is not always the case with research based on DOI). Furthermore, many of the empirical studies found were performed in an organizational context. Because this research was provoked by the interest in finding variables that could be of influence on residential adoption of broadband, we excluded the literature that focused strongly on the role of management, technical staff and culture of the organization (for example Carter, Jambulingam, Gupta and Melone, 2001). As a result of this analysis 12 suitable empirical studies based on DOI and 18 appropriate papers on TAM were included in our meta-analysis. A shortened version of the references to these papers are included at the end of this paper. Of course we are aware of the possibility that we have missed relevant papers, despite our extensive search efforts. However, using OpenKI as our tool, it is easy to go back, add papers and analyze the data again. Moreover, we are convinced that the papers we did use provide a meaningful and representative sample of research papers on the residential adoption and use of IS.

2.2 The OpenKI Tool

Further analysis of the papers that were found was done based on the Open Knowledge Infrastructure (OpenKI) tool, described by Van de Wijngaert, Brinkkemper and Bouwman (2006). The OpenKI tool is an online database (available at www.cs.uu.nl/people/lidwien/openki) that is accessible to any researcher who wants to add or to search content. In other words, anyone can enter their own data and use it for analysis or use the data of others for secondary analysis. With this approach, in which research efforts are shared we can accumulate knowledge with regard to IS as well as other research domains on a much larger scale than a single researcher would be able to.

The database supports the storage of meta-data about and content of the paper. The meta data concerns the type of publication (e.g. journal, conference), the abstract, key words, reference (e.g. journal, year, volume, issue, publisher). The content concerns the theory or theories taken as a starting point, research method(s) used, design (e.g. one shot), sampling (sample size and description) and data gathering (e.g. setting, structure, method), independent and dependent variables, level of analysis (e.g. interval, ratio), type of relation (causal, similarity), result description, support/reject and a measure of support (very strong to very weak). From the results section of the papers that were analyzed we extracted if and to what degree hypotheses were supported or rejected. Also a measure of strength of support that was found was reported in the system. Significant correlations were entered when p levels drop below 0,05.

2.3 Aggregation of the Variables

An important step in the analysis was putting variable names into categories at a higher level. The reason for this is to reduce doubling of terms (for example ’usage’ and ‘use’) and complexity. Figure 4 in the next section shows the complexity of a network looks that is not aggregated. In the aggregation process it is important that the researchers try to avoid aggregating too much, resulting in too abstract meaningless constructs. The researchers reviewed all variables and relationships carefully. With this qualitative clustering the number of variables for the hypothesized relationships was reduced. While interpreting and clustering the variables we tried to eliminate subjective interpretations as much as possible by debating about the aggregation steps among the researchers. We did retain all the original variables, so if in the analysis a relationship could not be interpreted or explained, we could fall back on an analysis of the original data for that part.

2.4 Network Analysis

Networks are defined by nodes and ties or links. Nodes can, for example, be actors (in case of actor networks). Ties are the relationships between these nodes (Wasserman and Faust, 1994; Hanneman and Riddle, 2005). Network analysis is increasingly popular in studies that aim to understand organizational communication and knowledge exchange. Using concepts and procedures from network analysis, we are able to analyze the collected data. The concepts can be considered the nodes in the network, and the links in the network represent the hypothesis or the relationship between the concepts. Using Netminer II from Cyram we are able to visualize 'conceptual networks' using for example the spring algorithm. Furthermore, we can use the basic measures in network analysis: size and density. Size is the number of nodes (concepts) in the network. Network Density measures the level of connectedness among the concepts in a network. It is computed as the number of present lines divided by the maximum possible number of the lines among all of the nodes. Two other central measures in social network analysis are In-Degree (D_{in}) and Out-Degree (D_{out}). Din relates to the number of lines that are incident to it. Dout refers to the number of lines that are incident from it. There are many more analytical tools that can be borrowed from social network analysis. Examples are structural holes, communities and power distance. In this paper we will limit ourselves to some of the basic network characteristics.

3 RESULTS

3.1 Analysis of TAM-Papers

In the 18 articles based on TAM that were included in our meta-analysis, we found a total of 247 hypothesized relationships. Of these hypothesized relationships 63 eventually were rejected after empirical research. As this image can not be interpreted like this, we aggregated the concepts as described before. For TAM, the aggregation was rather straight forward. For example, the concepts Usage behavior and Usage were aggregated to Use. The aggregated version of hypothesized relations consists of 30 nodes.

The first two columns of Table 1 compares the results for the theoretically posed hypotheses and the hypotheses that were actually supported through empirical research. If we compare the two columns we see that 184 of 247 posed hypotheses are supported (a decrease of 74%), resulting in a decrease of 17 unique relationships (a decrease of 84%). Other findings are that the density of the network drops from 0,28 to 0,21.

Table 1. Theoretical and Empirically Supported Concepts and Relations for TAM and DOI

	TAM		DOI	
	Theory	Empiric	Theory	Empiric
Number of variables in the network	30	30	34	34
Number of unique links in the network	106	89	85	69
Sum of all links in the network	247	184	116	85
Density of the network	0.284	0.211	0.103	0.076
Mean: average number a variable was mentioned	8.23	6.13	3.412	2.5
Number of isolates in the network	0	4	0	2
Number of transmitters in the network	14	10	23	22
Number of receivers in the network	0	0	2	2
Number of carriers in the network	1	1	0	0
Number of ordinaries in the network	15	15	9	8
Correlation Theory / Empiric	0.97		0.90	

Both in the theoretical as well as the supported network we see that the most variables are either transmitters (lines going out; independent variables) or carriers (lines going in and out; mediating

variables). When we look at the supported relations, we again see 30 variables, but four of them are isolates, which means that those variables do not have relationships with any other variable in the network.

When we draw a scatter plot for the sums of D_{in} and D_{out} for the theorized and empirically validated results we obtain insight into how well a theoretical framework performs in practice (see Figure 1). The first thing that stands out when looking at Figure 1, is that there is a strong linear relationship between the number of times a concept is mentioned in a theoretically posed hypothesis and the number of times it is supported in empirical research. In the situation that all theoretically posed relations are empirically validated the (linear) regression line is Y=X. In practice, of the line is less steep because not all relations are found to be significant. However, the steepness of the regression line we draw tells us something about the performance of a theoretical framework, especially in relation to another theoretical framework. Secondly, we see three clusters of variables: the ones that are tested only a few times (1), the ones tested in a small number of studies (2-11) and the ones that are tested in almost every TAM study. Moreover, we see that the concepts that are above the regression line are concepts that are relatively easy to prove empirically (e.g. Facilitating conditions, Perceived usefulness, Use) whereas the concepts that drop below the regression line perform relatively weak (e.g. Social influence, Experience, Perceived Ease of Use) The mediating variables experience and gender show mixed results.

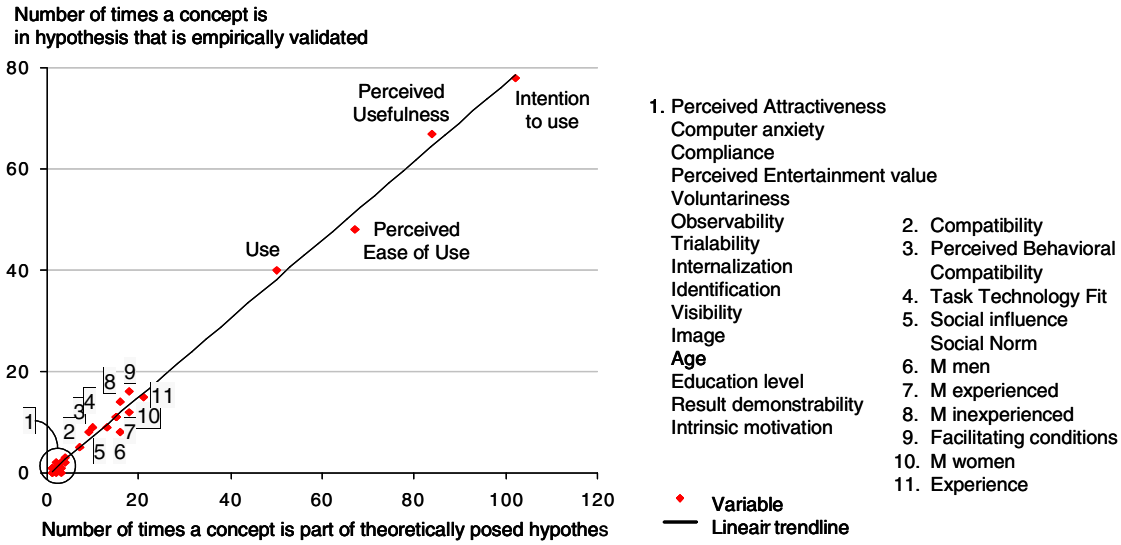

Figure 1. Relation Between Theoretically Posed and Empirically Validated Concepts for TAM

As a next step in our analysis we look at the main incoming and outgoing lines in the network of supported relations in Figure 2. From the picture, the concepts that were used less than five times as well as mediating concepts were omitted. Figure 2 tells us something about which concepts are explained in a theory and which concepts explain those concepts. In other words, the picture shows us the main dependent and independent concepts. The main dependent variables are shown at the bottom of the figure: Intention to Use and actual Usage. A remarkable result is that many studies stop at Intention to Use, but do not explain actual Usage. Perceived Ease of Use and Perceived Usefulness, Experience, social Influence and Social norms are the main independent variables. However, we also see that Perceived Ease of Use and Perceived Usefulness are not only independent concepts, they are also the dependent concept in a substantial number of hypotheses. The other way around, the main dependent variables Intention to Use en Use also explain other variables. This shows that in TAM research the dependent and independent concepts are strongly interrelated.

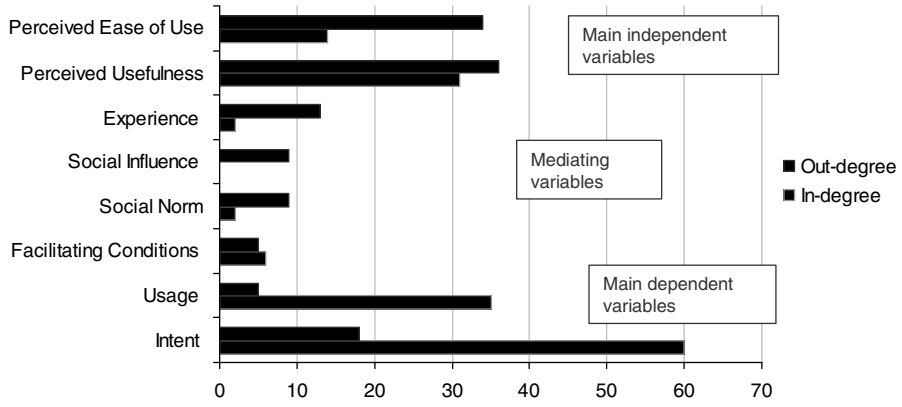

Figure 2. Main Ins And Outs in the Network of Supported Relations (TAM)

Putting it all together, we present the TAM model as a network in Figure 3. The size of the nodes is bigger for those mentioned more often and mediating variables are denoted with a triangle. Moreover, hypotheses that are mentioned more often are depicted with darker lines. From Figure 3 we can see that also here it becomes clear that the Intention to use is the most often mentioned dependent variable. Also perceived usefulness (PU) is dependent on many variables, but in itself PU also affects other variables. Perceived ease of use (PEOU) and actual usage (Usage) are slightly less frequently mentioned, but are also very central constructs in the supported model. In the new TAM model based on empirically tested and supported relations, we see the core constructs of TAM as main constructs: PU, PEOU, Intention and usage. Also social norms, experience (direct and as mediating variable) and facilitating conditions appear to be important (independent) variables in the network.

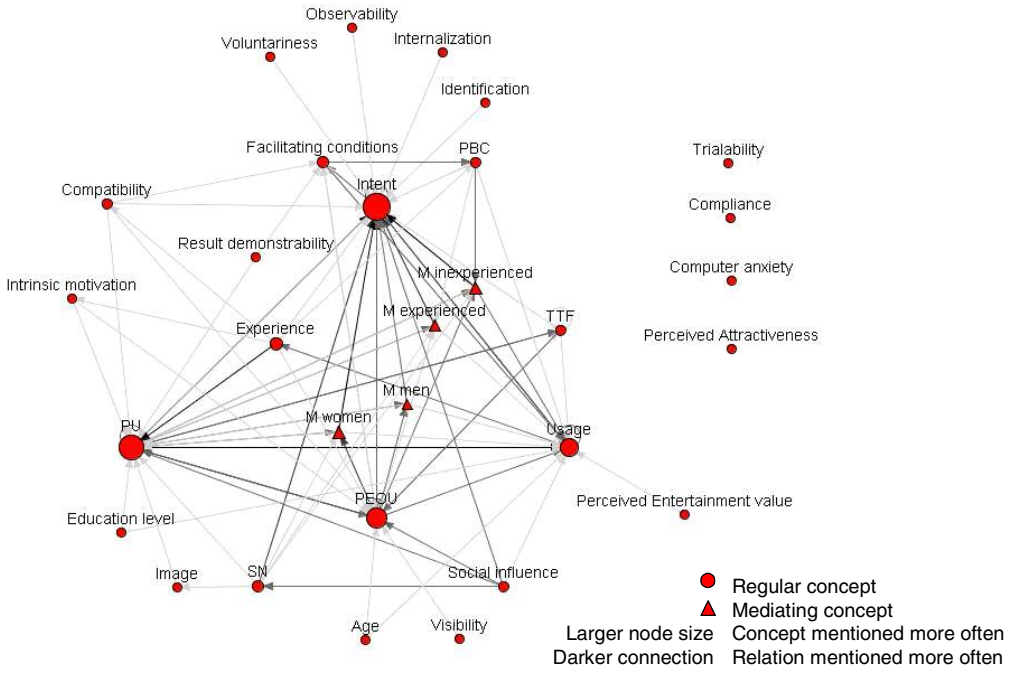

Figure 3. Accumulated Network of Supported Relations (TAM)

3.2 Analysis of DOI-Papers

In total, 12 papers were entered in the OpenKI database, yielding 120 hypotheses 99 different variables (Table 1). After aggregation, 34 variables were retained for further analysis. Due to aggregation 4 relations pointed at them selves (e.g. user characteristics influence user characteristics). These hypotheses were omitted in the analysis. From the 116 (85 different ones) hypotheses that were posed in the papers, 85 (69 different ones) were supported in empirical research. This is a decrease of 73% over all relations (and 81% for all unique relations).

In the DOI papers most variables are transmitters, both in the theoretical and empirical network. Second largest is the group of carriers. Two variables are receivers and there are no carriers in the network. We see the two isolates emerge in the empirical network. These variables (costs and gender) have no connection to the network anymore.

Similar to our analysis of the TAM papers we looked at how well the concepts stood up against empirical analysis. The scatter plot in Figure 4 tells us that the variables on the top-right side are in many different papers whereas concepts on the lower-left hand side are studied less often. Also here we see strong linear correlation, though slightly less than the TAM relations. Again the concepts below the trend line (e.g. Self Efficacy, Adoption Intention) being relatively harder to prove when put to the empirical test then the ones that are on top of the line (e.g. Usefulness, Adoption and Use).

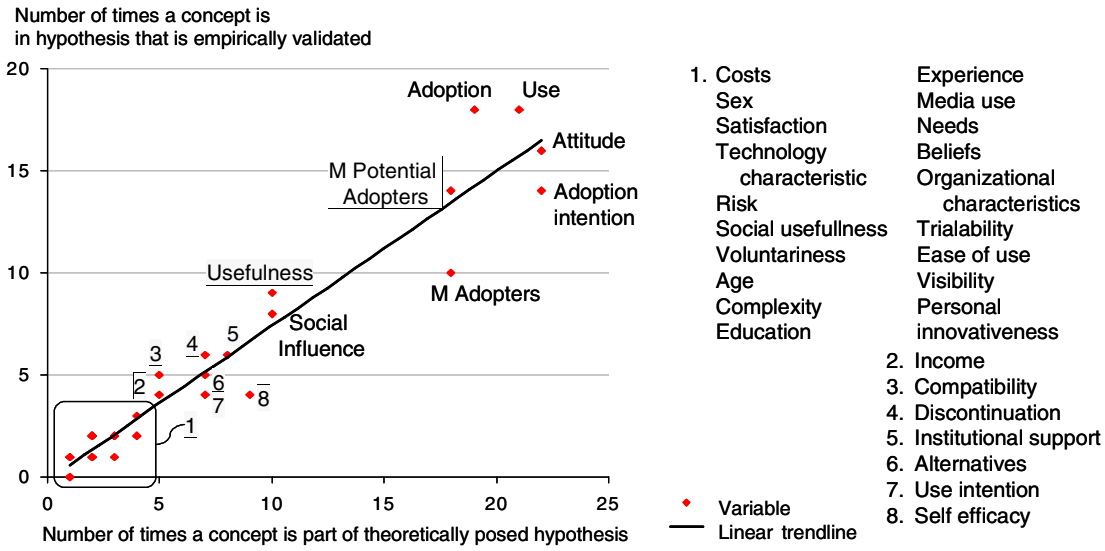

Figure 4. Relation Between Theoretically Posed Variables and Empirically Proven Variables (DOI)

Figure 5 shows the in and out relations of the supported network. Much more than in the TAM papers, there is a strong division between independent and dependent variables. The most important predictors are usefulness, institutional support, and the mediating variable Adopter category. Attitude, Adoption Intention, Adoption, and Use are the most important dependent variables. Also based on the density index of the network we can conclude that DOI is a much 'looser' network than TAM.

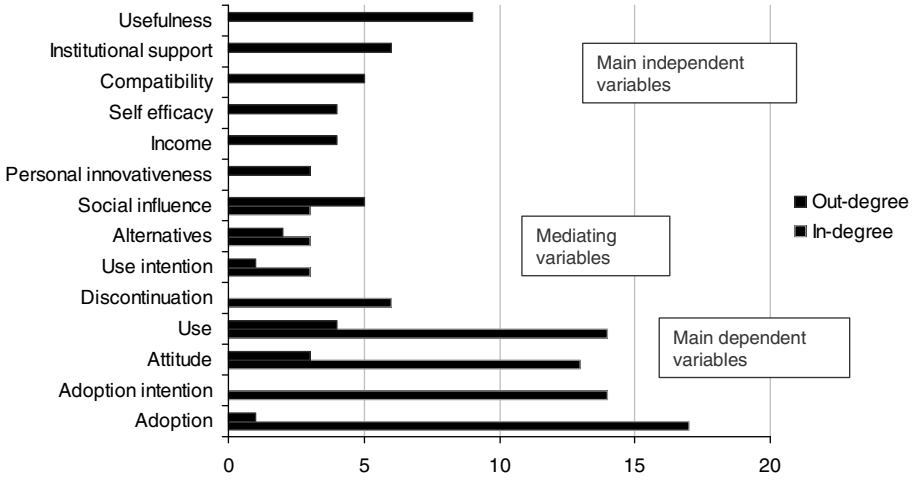

Figure 5. Main Ins and Outs in the Network of Supported Relations (DOI)

In Figure 6 we again accumulate results in terms of a network. In the picture we see that adoption of a new technology is related to user characteristics such as Education, Experience, Age and Income. Actual use is related to variables such as Self Efficacy, Complexity and Risks. A remarkable result is that there is no direct relation between Attitude, Adoption intention and Adoption.

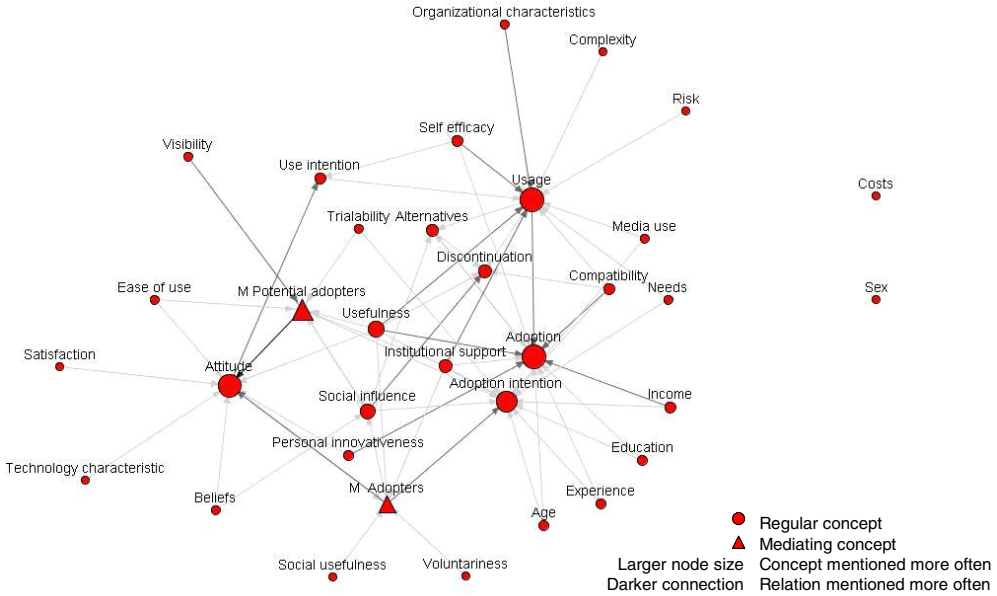

Figure 6. Accumulated Network of Supported Relations (DOI)

4 CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The aim of this research was to gain insight into the state of theory for two frequently used theories in the IS field, being DOI and TAM, using a network approach towards meta-analysis and the OpenKI tool. Moreover, we specifically looked at the sub domain of residential broadband adoption. This was done by comparing hypothesized relations with empirical results in a set of selected quantitative research papers. Moreover, the aim was to gain insight into the possibilities and limitations of performing meta-analysis with the aid of the OpenKI tool and network analysis. In this section we will provide some concluding remarks with regard to both subjects.

4.1 The Possibilities and Limitations of the OPENKI method (RQ1)

Based on the results of this research we believe that concept networks that accumulate different research papers can be made and help our understanding of the (empirical) strength of IS theories. The network approach towards meta-analysis provided an innovative way to accumulate research in the IS-field. A meta-analysis such as this one can help to determine which theory is best used as a conceptual model for further research, for instance in relation to the residential adoption of broadband internet. With the aid of network analysis of hypothesized and validated relations, a measure of overall empirical support for a theory can be given. The advantage of our approach towards meta-analysis is that a concept network can be visualized.

Moreover, concepts that are developed in (social) network analysis turn out to translate well to concept networks. Using quantitative network measures such as density and degree, networks from different theoretical frameworks can be compared to each other. There are some limitations to this research too. This study focused on empirical research in which hypotheses were clearly stated. For theoretical and qualitative studies it is more difficult to extract the central concepts. However, there are content-analysis techniques that can help to discover the central hypotheses in a paper (see for example Van de Wijngaert et al., 2006). A second issue with regard to the network approach in this paper is that now only basic network measures were used in the analysis. Future research can and should focus on more elaborate network measures. Examples are communities (discover clusters of concepts) and structural holes (discover new research area's). Moreover, the development of the network in the course of time can be used to understand theory development from a historical perspective.

With OpenKI we have developed a tool that supports the systematic accumulation of empirical research. This tool can be used in with regard to theories in the IS-field, as well as other research area's. Moreover, OpenKI provides a unique opportunity to share insights. Researchers from over the world can add papers to the central database. They can analyze their own entries and/or combine them with the entries of others. Others can, in their turn also make use of the data in the central database. Of course a fast growth of the number of OpenKI users would imply a more elaborate monitoring system. Future research with regard to the OpenKI tool can focus on different areas. First of all, the user friendliness of the system can be improved. Secondly, many functionalities such as additional search possibilities and an aggregation function (now done manually) can be added. In an ideal situation researchers could for example have the opportunity to dynamically switch between high and low aggregation levels. Moreover, also a network function can be integrated. This would allow the possibility to directly generate network pictures as well as other pictures such as Figure 5 and 6.

4.2 Key concepts and empirical value of TAM and DOI (RQ2 and RQ3)

With regard to the two frameworks, we have shown an extensive analysis of the core concepts as well as their empirical robustness with regard to residential adoption of broadband internet. We can conclude that although the two frameworks may be different theories and although variable names may be different, the theories do also share many concepts. A substantial part the results for the two frameworks are overlapping. Usefulness, Use intention, Attitude towards using and actual Use are concepts that emerge in both frameworks.

However, there are also some differences between the two frameworks. The most striking difference between the two frameworks is that TAM concepts seem to point at each other as explanatory factors. DOI, in contrast makes a clear distinction between dependent and independent concepts. This result would imply that DOI is a more meaningful theoretical framework. However, when we look at the empirical strength of the two theories, DOI scores lower than TAM. This may also be explained by the fact that TAM concepts are closer to each other than the DOI concepts. In other words, we conclude that TAM primarily explains itself, because the relatively sparse concepts in the original TAM are so closely related to each other. This parsimony and its relatively strong predictive power make TAM applicable to different situations, but this strength is also an important limitation: TAM is predictive

but its generality does not provide sufficient understanding of the adoption of new technologies by users (Mathieson 1991; Venkatesh, 2000). DOI tends to provide a broader view on user adoption of new technologies.

In this research we chose not to combine the results of TAM and DOI in one 'big' network of concepts. The reason for this is that we feel that other frameworks such as Media Richness, Social Influence Model, Domestication, Social Exchange Theory and Task Technology Fit should then also be added. Future research, using a network approach towards meta-analysis and OpenKI may help to link these theories and models to each other.

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Appendix I - Literature included in the META-analysis

TAM	DOI
Adams, Nelson and Todd, 1992	Stern, Gregor, Martin, Goode and Rolfe, 2004
Burton-Jones and Hubona, 2005	Li, 2003
Dishaw and Strong 1999	Hung, Ku and Chang, 2003
Heijden, Van der, 2003	Eastin, 2002
Hubona and Geitz, 1997	Flanagin and Metzger, 2001
Jiang, Hsu and Klein, 2000	Beatty, Shim and Jones, 2001
Klopping, and McKinney, 2004	Tan and Teo, 2000
Malhotra and Galetta, 1999	Liao, Shao, Wang and Chen, 1999
Mathieson and Peacock, 2001	Karahanna, Straub and Chervany, 1999
Oh and Ahn, 2003	Parthasarathy and Bhattacherjee, 1998
Sun and Zhang, 2006	Lai, 1997
Szajna, 1996	Dickerson and Gentry, 1983
Taylor and Todd, 1995a	
Taylor and Todd, 1995b	
Venkatesh and Davis, 2000	
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Vishwanath and Goldhaber, 2003	