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# Identity Management Systems Research: Frameworks, Emergence, and Future Opportunities

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# **IDENTITY MANAGEMENT SYSTEMS RESEARCH: FRAMEWORKS, EMERGENCE, AND FUTURE OPPORTUNITIES**

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## **Abstract**

*Identity and identity management are an emerging area in academic research and consolidation of the discussion on what compose their issues is just beginning. Identity Management Systems (IdMS) is another key element of research involving the identity and identity management domains. As digital identity becomes more and more important in the online world, the emergence of IdMS has brought about primary changes to different online contexts. The purpose of this paper is to provide an assessment of the state of IdMS research and analyse the extant studies. Accordingly, we comprehensively review the research on IdMS that has been conducted in different fields. We also reveal the emergence of IdMS research domain and its current status by using a detailed analysis and taxonomy of 106 publications from key research outlets. This paper develops a framework for classifying the studies, reviews key findings, and identifies opportunities for future research into IdMS.*

*Keyword: Identity; Identity Management Systems; literature review; taxonomy; cross-disciplinary*

## **1 Introduction**

Nowadays, personalized services such as eGovernment, eCommerce and eHealth applications involve and process significant amount of personal information. This has contributed to the growth of online identities, which contain a great deal of information about users including personal attributes and behavioural preferences as well as access-related metadata. The growing use of information and communications technology (ICT) in numerous contexts such as the increasing presence of organizations on the Internet have increased the need for users to examine closely how they represent themselves online and who they are actually interacting with (Josang et al., 2007). These services represent a shift not only from a technical development perspective but also from a traditional concept of identity to one that is socio-technically driven toward facilitating social interactions and services (McLaughlin et al., 2010).

Identity is an emerging theme in academic literature (Halperin, 2006), and identity management has been identified as an emerging field and a key research topic for future decades (Halperin et al., 2008; Pfitzmann and Hansen, 2010; Jensen and Jaatun, 2013). Online identity management is fundamental to the further development of the Internet economy (Smedinghoff, 2012). Identity management is described as the framework and system used in computer or communication systems to control identity (Dabrowski and Pacyna, 2008). Identity management is important in different contexts, including within the enterprise, e-commerce and government, to underpin business processes and services and enable digital interactions and transactions from a consumer's perspective (Mont et al., 2003). Identity Management Systems (IdMS) comprise a key research topic in the identity and identity management domains. IdMS, a new and innovative information technology (IT) artefact, involve the integration of emerging technologies and business processes to create identity-centric approaches for the management of users, their attributes, authentication factors and security privileges across the systems within multiple organizations.

As digital identity has become more important in the online world, IdMS are essential components for the successful growth and development of the next, so-called "3.0", user-centric Internet services. Furthermore, secure, reliable and user-friendly IdMS are considered fundamental in establishing trust, such as in e-commerce applications (Alpar et al., 2011; Smedinghoff, 2012). It has been suggested that IdMS is a basic feature of the IT infrastructure and should be put in place before governments, organizations and commercial enterprises start rethinking citizen, customers and services relationships to accommodate the changes induced by Web 2.0 (Ostergaard and Hvass, 2008; Smith, 2008). The management of IdMS has been high on the agenda of most governments for the last decade (Seltsikas and O'Keefe, 2010).

Research in various areas such as computer science, engineering, information systems and social science has been the emergence of a new research stream. The last four years have seen an increasingly growing number of research projects and papers in existing books, journals and conferences in the topic of identity management and IdMS. In addition, there have appeared various journals focussing on identity and identity management, special tracks of IdMS in conference, and entire books, journals and conferences devoted to aspects of identity and IdMS.

The importance of these issues calls for research into the topic of IdMS and its emerging formations. It seems timely, then, to take an overall view of what is being done and what is still left to do and to consider how the researchers are approaching IdMS issues.

The main objective of this paper is to assess the state of art in IdMS research. It aims to review the pre-existing and ongoing work in IdMS that have been conducted in a variety of fields over the past

decade. This study attempts to characterize the development and the relationships among extant research studies of IdMS. It also discusses some gaps which represent future implications and opportunities in this emerging area in order to build a strong research tradition. The paper provides IdMS research framework derived from the technical–formal–informal (TFI) model (Stamper et al., 2000) which represents an information system as being made of technical, formal and informal layers.

The paper is organized as follows. The next section introduces the state of the art of IdMS research. Then, discuss the method used to gather and analyse the data. Next, the findings of the analysis are presented and discussed. The paper's conclusion provides a summary and highlights some implications for future research directions into IdMS.

## **2 The Innovation of the Identity Management Systems Research Framework**

In information systems (IS) research; there is an established tradition of examining the research literature itself to better understand the research's *state of play* in the field and to distinguish patterns in the development of the field itself (Alavi and Carlson ,1992; Banker and Kauffman ,2004). In this regard, one of the main objectives of this study is to understand the state of IdMS research through an examination of the existing IdMS literature.

In order to analyze the current research in the IdMS field, it is helpful to have a conceptual framework that aids in the classification of IdMS research. This study employed a *technical–formal–informal (TFI) framework* (Stamper et al., 2000) (see Figure 1) which conceptualizes and separates IS into three different but interrelated layers: technical (T), formal (F) and informal (I) (Liebenau and Backhouse, 1990; Liu, 2000; Stamper et al. ,2000; Halperin ,2006). We adopted this model as the layers enable a holistic approach to the study of IS and related themes, so that the layer to which specific research relates can be readily understood and its place within the context as a whole ascertained (Halperin, 2006). In addition, the TFI model can be used to identify gaps in the literature and to provide implications for future research and practice (Halperin, 2006).

The TFI framework is based on semiotic theory (semiotics) (Stamper et al., 2000). Semiotics, also called semiotic studies, is the study of signs (i.e. something that can be interpreted as having meaning) and the sign processes, and how they facilitate communication. Semiotics is divided into three components: syntactics, semantics and pragmatics (Liebenau and Backhouse, 1990, p.11-79). Syntactics provides relations and rules among signs in formal structure. Semantics represents the relation between signs and things to which they refer to the transfer of intended meaning. The meaning of data is often linked with a particular context. Therefore, the focus of semantics is the relationship between what is being transmitted and what is being understood. Pragmatics is the way in which understanding prompts action and in which context contributes to meaning. Pragmatics represents the relation between signs using agents (Liebenau and Backhouse, 1990).

The three layers of the TFI model that are applied to IS have been defined as follows (Liebenau and Backhouse ,1990; Stamper et al. ,2000; Halperin ,2006). The *technical layer* refers to the information technology component, which contains hardware, software, protocols, data formats and the design of the technology, such as the layout and interface of the system. The *formal layer* refers to the shared understanding of attributes and their formal procedures, policies and rules, regulations and standards as well as other forms of bureaucracy. The *informal layer* of a system refers to the ability to operate in contexts and attributes across domains. It encompasses the uses, behaviours and systems of belief that govern the perceptions, expectations and values of the individual members of the system. The layers of the TFI model are interdependent. Stamper et al. illustrated this interrelationship explaining, “*Informal* norms are fundamental, because *formal* norms can only operate by virtue of the informal

norms needed to interpret them, while technical norms can play no role ... unless embedded within a system of formal norm” (Stamper et al. 2000, p. 19).

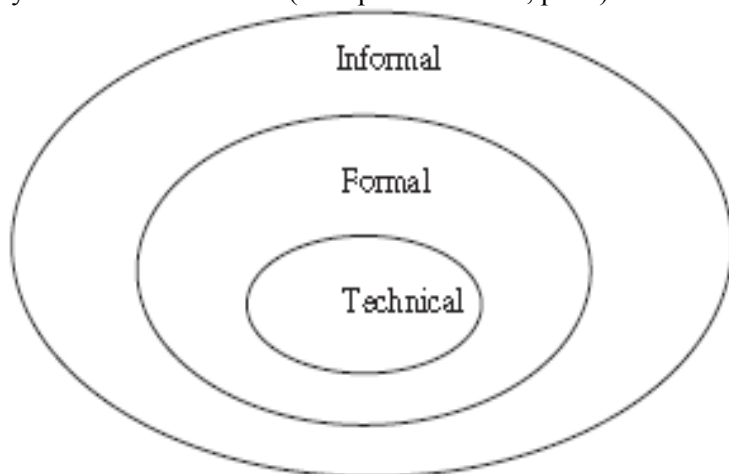


Figure 1. The TFI model of information systems (Source: Stamper et al., 2000).

### 3 Research Method

A *structured literature review* was conducted to assess the most innovative and current literature in IdMS. The structured literature review is espoused by Tranfield et al. (2003) and can be considered as a means by which important literature central to and underpinning the research can be rigorously and systematically mapped out (Armitage and Keeble-Allen, 2008). It has been argued that this is an appropriate approach in conducting a broad topic with a relatively small number of research questions which is opposite to systematic literature review that is usually associated with a detailed and narrow topic and is driven by a specific research question (Kitchenham et al., 2011). Structured literature review provides an overview of a broad research area by synthesizing major themes and issues and categorizing previous research with respect to defined categories (Armitage and Keeble-Allen, 2008). As this review focuses on the broad IdMS literature, using a structured review is an appropriate approach. It is necessary to carry out a systematic approach to ensure the quality of the review results (Tranfield, et al., 2003; Kitchenham 2004). Therefore, we followed the review method guidelines proposed by Tranfield, Denyer and Smart (2003), Kitchenham (2004), Armitage and Keeble-Allen (2008) and Kitchenham et al. (2011).

The scope of the literature was limited to the time frame from January 2000 to August 2013. The literature review was carried out until mid 2013 (the close of this research project). For that reason, the time frame was limited to August 2013.

The general guidelines for the publication selection were as follows:

1. The central theme should be identity, identity management or IdMS;
2. Papers should have contained at least one section discussing IdMS; and
3. Selected articles should be in the IS, IT, computer science or social-science domains.

Relevant papers reflecting IdMS were retrieved from the following databases: *Scopus*, *Science Direct*, *ProQuest Science Journals*, *ACM Digital Library*, *IEEE Explore* and *Google Scholar*. The search strategy identified articles with the following keywords: *identity*, *online identity/electronic identity/digital identity*, *federated identity*, *identity management*, *identity management system* or

*identity management technology* as the subject headings or text words in titles and abstracts. This link [https://docs.google.com/file/d/0B1DOO8XSG0yyMi1iNIVhbWN6R3c/edit?usp=docslist\\_api](https://docs.google.com/file/d/0B1DOO8XSG0yyMi1iNIVhbWN6R3c/edit?usp=docslist_api) provides a description of the publications identified in the selection phase of the literature review (please copy and paste the link to direct you to the webpage).

Results of this search strategy produced a list of 300 resources, 194 of which were excluded as they did not meet the inclusion criteria. In total, 106 published papers were selected for detailed analysis and categorization. Table 1 shows the publication distribution source types as well as the percentage of total publications in each IdMS source type. Appendix 2.2 provides a description of the publications identified in the selection phase of the literature review.

Source	Number	%
Journal Articles	41	38.7
Conference Proceedings	29	27.4
Technical Reports/White Papers	25	23.6
Books/Book Sections	11	10.3
Total	106	100

*Table 1. Distribution of publications.*

In order to assess the state of IdMS research, the following questions were posed:

1. What is the field of research (e.g. computer science, IS/IT or others)?
2. What is the main focus of research (e.g. individual, business or technical)?
3. What is the nature of research (e.g. empirical, conceptual or review)?
4. What is the category of research (according to the TFI model)?
5. What are the key application areas involved in IdMS research?

Prior literature analyses demonstrated that these questions allow researchers to successfully synthesize identity-related research (Halperin 2006) and other research fields in the IS discipline (Alavi and Carlson ,1992; Hoehle et al., 2012). In order to answer the questions above, the publications needed to be carefully categorized and a framework needed to be developed. The findings and framework are described below.

## **4 Findings and Analysis**

It is clear that IdMS is an emerging research topic that has expanded rapidly and attracted a number of researchers, especially in the last six years. Figure 2 presents the number of publications per year and shows an overview of the growth of this research niche.

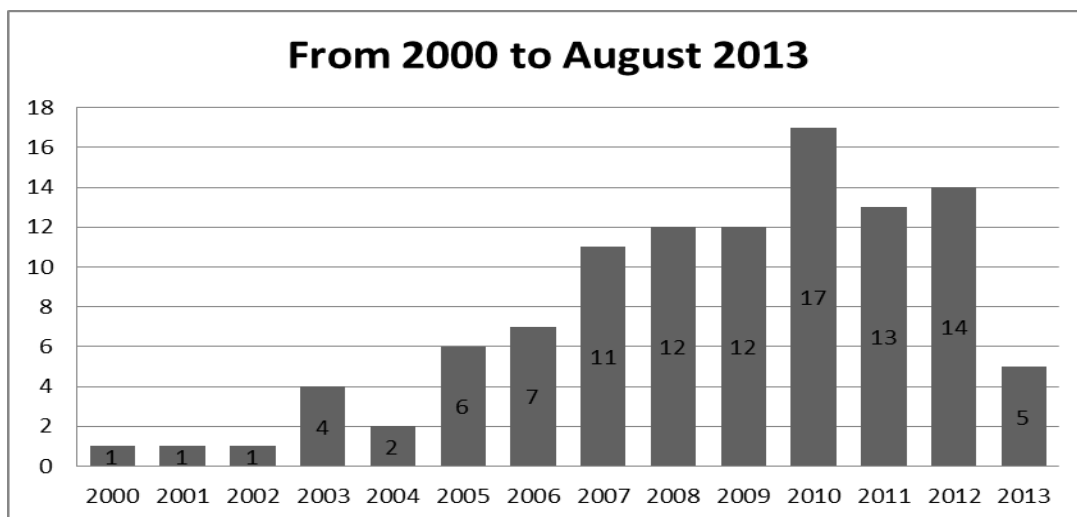


Figure 2. Number of publications per year.

#### 4.1 The field dimensions

The analysis yielded several categories that represented the range of disciplines in IdMS research. This analysis considered the relevance of diverse disciplinary standpoints and the use of related theories and conceptual models to identify research in IdMS. 64% of the papers were from computer science literature; 19% were IS/IT literature; and 17% were from other social science domains, such as management, economics, organization theory, psychology, law, social policy, etc. Our findings indicate that there is a lack of published work in identity and IdMS research from the IS field. This supports Seltsikas and O’Keefe’s (2010) argument that published research directly related to the topic of IdMS was sparse particularly in the established IS journals.

#### 4.2 Research focus

A thorough analysis yielded four perspectives that represented the range of the research focus in the IdMS field. Each article was classified into one of the following four categories: individual, business, technical and general. Table 2 presents the distribution focus for the IdMS research in the sample.

Perspective	Definition	Number	%
Individual	User applications, user behaviour and the implications of IdMS for users.	17	16
Business	Business applications, IdM providers’ impact and the implications of IdMS for businesses.	23	21.7
Technical	Underlying security technologies, technical developments and solutions and frameworks for IdMS.	40	37.8
General	General issues, including broad and non-specific focus on IdMS.	26	24.5
Total		106	100

Table 2. Focus for the IdMS research.

The individual perspective included publications that focused on user applications, user behaviour and the implications of IdMS for users. The individual perspective emerged as the least mature area of IdMS research. This body of work encompassed papers related to the use and behavioural beliefs of IdMS users. For example, Satchell et al. (2011) studied the relationship between identity and technology from users' perspectives. Adjei and Olesen (2011) attempted to understand the relationship between users' intentions to disclose personal information, their actual personal information disclosure behaviours and how these can be influenced to develop privacy-enhancing IdMS that the users can trust.

The second perspective was defined as the business perspective. The business perspective emerged after the individual perspective as the least popular area of IdMS research. The analysis of the literature show that IdMS research from the business and individual perspectives is limited. The business perspective encompassed papers that focused on business applications at the organizational level, IdMS providers' impacts and the implications of IdMS for business and governments. Ivy et al. (2010) and Jensen and Jaatun (2013) identified some key factors contributing to the adoption of federated identity management systems from the organizational level. These factors included technological complexities, cost, usability, privacy, lack of trust between partners, and the complications and expenditures involved in establishing and maintaining contractual agreements between partners. Some studies in this perspective (e.g. Seltsikas and O'Keefe, 2010; Baldoni, 2012; Ferdous et al., 2012) contributed to a better understanding of IdMS issues in e-government context. These studies attempted to develop, implement and maintain the issues of IdMS that are facing stakeholders in government.

The technical perspective encompassed articles dealing with IdMS in a technological context that focused on underlying security technologies, technical developments, and solutions and frameworks for IdMS. The technical perspective clearly emerged as the dominant perspective, yielding 40 studies. Many IdMS studies have stressed the importance of privacy, security and usability in IdMS; each study focused on particular issues or looked at the problem from a specific perspective. Research on IdMS is usually found in technical computing journals that deal with underlying security technologies, such as cryptography (e.g. Miyata et al., 2006; Ferdous & Josang 2013), and the research also recommended usable privacy-enhancing solutions (e.g. Josang et al., 2007; Dey & Weis 2010). Recently, Rossudowski et al. (2010) recommended an architecture that allowed a single smart card to be used in a dynamic, multiple-application environment. This architecture would protect all information communicated between the smart card and a specific application through the use of one-time passwords, maintaining the privacy of the person. Marmol et al. (2010) recently submitted a Trust and Reputation Management proposal (one of the first applied in IdMS) called TRIMS that recommended a domain that must decide whether or not to exchange necessary information with another domain, depending on its trustworthiness and reputation.

Finally, the general perspective in IdMS research emerged as a key category in the analysis of the literature. Papers in this category discussed general IdMS issues, and the category had a broad, unspecific focus. The Future of Identity in the Information Society (FIDIS) Network of Excellence provides rich information on the IdMS topic. For instance, Bauer et al. (2005) provided a systematic review of current IdMS. For an overview of recent developments in IdMS, see Meints (2009). Poetzsch et al. (2009) provided an overview of the features and requirements for FIMS and analyzed four FIMS frameworks (Liberty Alliance, Shibboleth, privacy and identity management for Europe project (PRIME) and Information Cards) on the basis of user requirements. Dhamija and Dusseault (2008) identified seven flaws or design challenges that should be fixed before the general community will use and accept IdMS. These flaws included identity task facilitation, ease of use and understanding, cognitive scalability (the user's overall cognitive burden), information disclosure, mutual authentication, consumer experience and trust. Dhamija and Dusseault (2008) argued that these aspects are important for achieving secure usage and wide acceptance of such systems, thus enabling



users to make suitable decisions about privacy. Ferdous and Poet ( 2012) provided a comparative analysis of a number of IdMS (i.e. OpenID, Liberty Alliance, Shibboleth, PRIME, Information Cards and OAuth) against a set of requirements for the privacy-enhancement of IdMS. They found that none of these IdMS were ideal in providing privacy-preservation yet were usable.

The analysis indicated that a large proportion of IdMS research has focused on technical issues, and little research has focused on the individual or business levels. This result is consistent with Seltsikas and O'Keefe's (2010) and Jensen (2012) argument that IdMS research from both the business and user perspectives is limited. This suggests that business and individual areas need more thorough development in future research.

### 4.3 The nature of research

To investigate the nature of IdMS research (research method and data collection), a classification was needed to categorize the selected publications. The strategy used for this classification depended on whether the IdMS literature was dominated by intuition-based reasoning and conceptual analysis or by empirical examination (Hirschheim ,1991). In this case, empirical research was considered to be all research originating in or based on observation or experience, independent of whether the researcher gathered data through primary or secondary data collection. Papers based on academic literature reviews and on intuition-based reasoning were classified as conceptual research. Studies with an unclear nature of research were classified as 'not available'. Regarding these classifications, 20 publications (18.9%) used empirical research, 76 (71.7%) were conceptual, and 10 (9.4%) were 'not available' (see Figure 5). Much of the literature was descriptive, dominated by intuition-based reasoning and conceptual analysis rather than empirical investigation. Given that IdMS is still in an early stage of development, much of its research is geared toward a conceptual examination aimed at building the foundations on which future research may be established.

As we mentioned previously, empirical investigation has been limited in the IdMS literature. The use of quantitative and qualitative methods as methodological approaches was limited. Of 20 empirical studies, 10 used qualitative methods, including interview (25%), focus groups (10%) and documentary evidence (10%), with another nine studies using quantitative methods including survey (15), observational data (10%), mathematical model (5%), event study (5%), experiment (10%), model checking and empirical evaluation techniques (5%). One study used mix-methods research. One study used mix-methods research (see Figure 3).

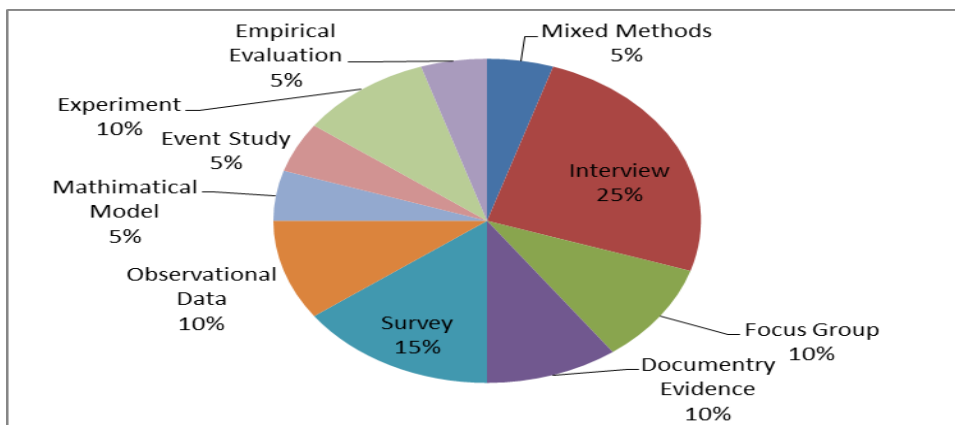


Figure 3. Classification of IdMS empirical research based on research methods used.

#### 4.4 The TFI layers

Having identified the different perspectives of IdMS research, the analysis of the literature was framed and classified using the TFI model, which was previously introduced. The analysis focused on how each of the selected papers related to the technical, formal or informal layers. After careful classification, we found that 47 (44.4%) studies were technical, 43 (40.6%) were formal and 16 (15%) were informal. Figures 4 and 5 show the publication distribution for each layer classified by each perspective identified in this study.

The findings illustrated that the technical layer was dominant, and that a reasonable amount of research had been undertaken in this category. Also, it appeared that the formal layer was well studied in previous research. The informal research layer has had little attention.

In the informal layer, previous IdMS studies considered the perspective of legislation, such as IdMS perceptions in an e-government context (e.g. Grimsley and Meehan, 2007; Aichholzer and Straub, 2010; Seltsikas and O'Keefe, 2010). There is a lack of research reported in the academic literature that focused on Web-based IdMS and investigated self-regulation IdMS, such as that in e-commerce and social media (Adjei and Olesen, 2011). Therefore, more research is needed focuses on self-regulatory IdMS that assumes rational behaviour from online users consenting to services in exchange for the release of identity information.

When the findings of the previously categorized perspectives were examined (according to the research focus and the nature of research), it was found that the analysis results accurately corresponded to the TFI layers identified here. Most publications categorized within the technological perspective corresponded to the technical layer of the TFI model. This finding is consistent with Halperin's (2006) argument that this type of research is characterized by the exclusive attention given to the technical component of IS where identity and IdMS issues were viewed through a purely technological lens. The technical perspective corresponds, to a certain extent, to the formal layer, but the informal context of technology is almost never addressed.

The individual and business perspectives corresponded almost equally to the formal and informal layers. The technical layer corresponded to the perspectives of businesses, providers and, to a certain extent, of the individual users. Finally, the formal layer of the TFI model corresponds directly to broad IdMS research, while technological perspective in the technical and informal context of IdMS is reasonably addressed (Figure 4).

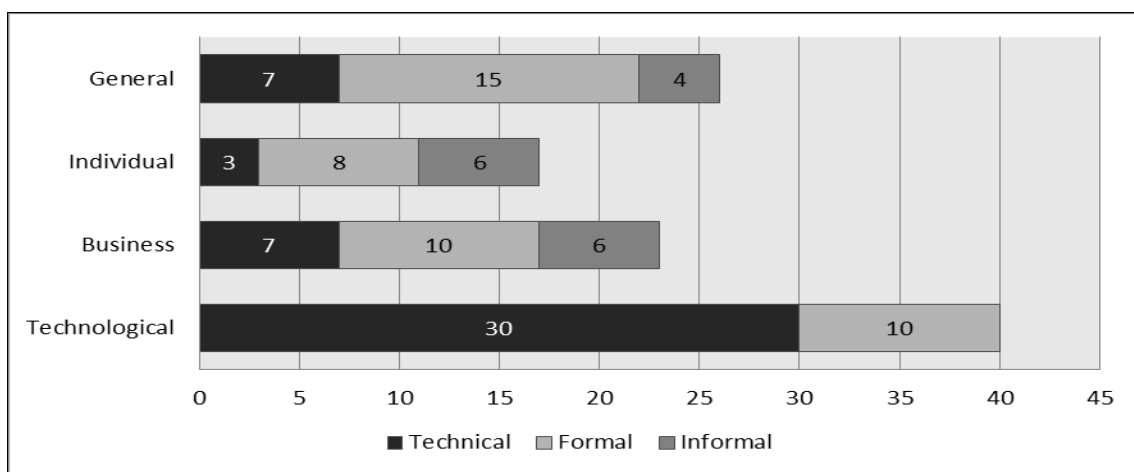


Figure 4. Distribution of research focus perspectives over the TFI categories.

The categorized research process also found that the categories corresponded to the TFI layers. Most papers categorized within empirical and conceptual research corresponded to their respective layer in the TFI model. However, the 'not available' category only corresponded to the technical and formal layers (see Figure 5). The analysis found that empirical studies were emerging but comprised a minor amount of research; the informal layer was adequately addressed in the empirical research category, and the formal and technical layers had been researched less. Quantitative research was not adequately represented, and just one study employed the mix method. Conceptual research primarily corresponded to both the technical and formal layers, but it also adequately corresponded to the informal layer. This indicates that there is little exploration about IdMS from an informal perspective. Thus, further research to explore and conceptualize users' perceptions of IdMS is needed.

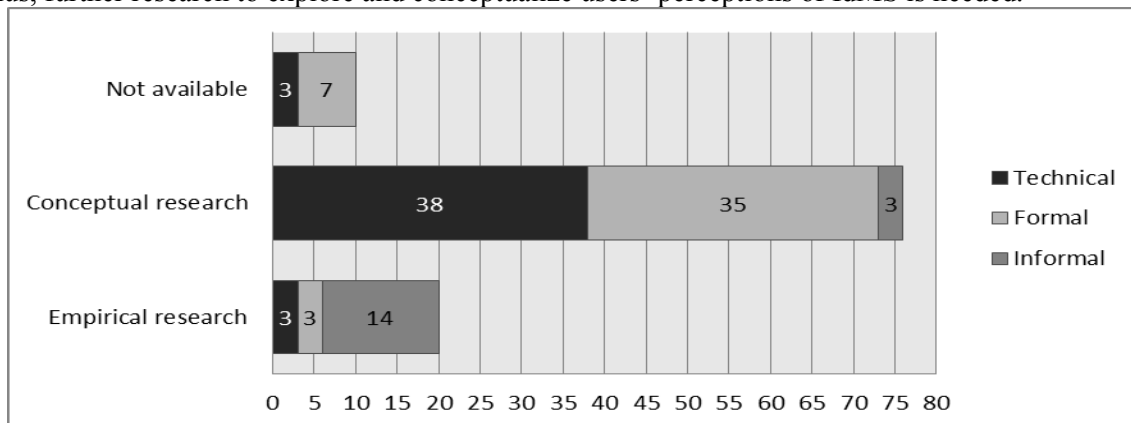


Figure 5. Distribution of IdMS by nature of research over the TFI categories.

It is clear that empirical research in IdMS has limited documentation compared to the conceptual type of work in all three layers of the TFI model. These findings also showed that there was a lack of informal-type IdMS research within different perspectives identified in this study. Figure 6 presents the IdMS research framework, providing all maps between the IdMS perspectives identified in this study.

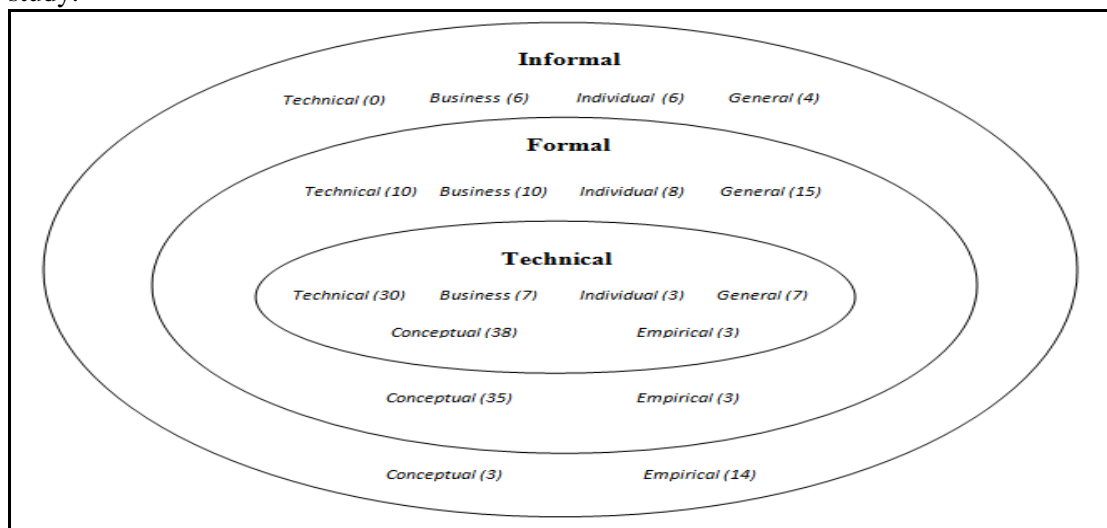


Figure 6. Identity management systems research framework.

Note 1: (x) indicates the number of studies in each category that was identified in this study.

Note 2: studies classified with a 'not available' nature of research (10) are not included in this framework.

## 4.5 Application areas

A wide range of application areas appear relevant to IdMS research, emphasizing the importance of sectoral analysis in this emerging field of research. However, it is still very early to allocate IdMS across entire sectors of corporate activity. Table 3 presents the classification that was developed and applied to each paper. This classification sought to reflect the application domain and primary topic of research.

Four application areas were dominant in the retrieved IdMS research. The most common application was IdMS technologies and services (16%) which were usually approached from a technical perspective. This application was approached in a very broad manner with several studies focused on a specific type of identity management technology. Federated identity management (FIM) and government topics also emerged as equally popular applications, yielding 15% and 11% of studies respectively in each application. Most studies of government applications highlighted and developed IdMS issues faced by stakeholders in government. The architecture and paradigm topic was the third emergent application (9%), and it was typically drawn from a general, formal perspective. The final dominant applications that emerged were crime detection and forensics and commerce/business applications, which yielded 8% and 7% of the research respectively. Research related to crime detection and forensics considered IdMS in relation to risk management and regulation, highlighting the critical challenges that cybercrime poses and providing some concerns about identity theft and fraud. Studies focused on commerce/business applications addressed the significance of IdMS as a vital marketing tool for commercial enterprise. In addition; they addressed IdMS trust issues, discussing the relationship between customers and service identity providers in e-commerce and financial applications.

Application	Number	%	Application	Number	%
Technologies and Services	17	16	Education	3	3
Federated identity management	16	15	Social network	3	3
Government	12	11	E-transaction	2	2
Architecture and paradigms	10	9	Online community	2	2
Crime detection and forensics	8	8	Mobile	1	1
Business/commerce	7	7	Culture	1	1
Privacy enhancing technologies	6	6	Personalized services	1	1
Design	6	6	Ethics	1	1
Terminology	5	5	Information society	1	1
Online identity	3	3	Digital ecosystem	1	1
			Total	90	100

Table 3. Distribution of IdMS studies according to their applied application.

Privacy-enhancing technologies, design and terminology areas were adequately documented in the current literature, yielding 6%, 6% and 5% of the studies, respectively. Studies related to privacy-enhancing technologies and design applications emerged from the technical level while research focused on terminology emerged from the informal layer. Education, social networks, electronic transactions and online community applications were less frequently explored areas in IdMS

research. It was also remarkable that, among previous studies, only one paper's main topic was the use of IdMS in mobile and personalized services.

#### **4.6 Gaps in the Identity Management Systems literature**

Many IdMS studies have stressed the importance of privacy, security and usability of IdMS, each focusing on particular issues or looking at the problem from a special perspective (e.g. Miyata et al. ,2006; Josang et al.,2007; Dhamija and Dusseault 2008; McLaughlin et al. 2010; Rossudowski et al. 2010; Armando et al. 2013). The majority of these studies focused on technical or design problems and challenges of IdMS. The findings show that there is a lack of a behavioural research in the IdMS domain. The extant literature indicates that previous studies have been paid little attention to the focus on the use of IdMS especially from the user perspective (Seltsikas and O'Keefe, 2010). In addition, the perceptions of IdMS from the individual perspectives are less explored (Satchell et al., 2011; García et al., 2012). Moreover, suitable models or frameworks for understanding IdMS from both the business and user perspectives are equally limited (Seltsikas and O'Keefe , 2010; Jensen ,2012). Although few studies have identified and suggested some factors and metrics towards the adoption of IdMS (e.g. Poetzsch et al. ,2009; Ivy et al., 2010; Adjei and Olesen ,2011; Jensen and Jaatun ,2013), there are no studies which empirically examine the factors that affect user adoption of IdMS. Also, there have been no theoretical models proposed and tested to better understand user adoption of IdMS. Therefore, the overall literature suggests that exploring and measuring users' perceptions of IdMS are needed (Poetzsch et al. 2009; Ivy et al., 2010; Seltsikas & O'Keefe 2010; Adjei and Olesen ,2011; Satchell et al. ,2011; García et al.,2012).

### **5 Conclusion and Future Recommendation**

This study provides a general overview of the main characteristics of the past and current states of IdMS research through the categorization and statistical analysis of the existing academic literature on IdMS. We reviewed previous research on IdMS in the fields of computer science, IS/IT and social science. Based on the TFI model, we categorized 106 key studies and introduced an IdMS research framework based on all possible connections between three different perspectives: the research focus (technical, business, individual and general), nature of research (empirical and conceptual) and the three TFI layers. Figure 6 provides a summary of this review. Our analysis revealed that each category focused on more than one layer of the TFI model at a time and considered the context of other layers. This indicates that there is a virtual cross-disciplinary research capability in IdMS. In addition, this paper highlighted the analysis in the field of IdMS and emphasized the application domains that are relevant to IdMS studies. IdMS research is likely to develop and mature into a research concept in its own right as the body of research grows. However, the results of our analysis suggest that for this to happen, researchers should focus their efforts more carefully. Some areas are promising candidates for future IdMS research. These areas are described below.

#### **Research from individual and business perspectives**

The majority of current studies focus on the technical or design problems and challenges of IdMS. Perceptions of online identity and IdMS from individual perspectives have not been thoroughly explored in previous research. Moreover, current research indicates that the provision of suitable frameworks or models to better understand IdMS from both business and individual perspectives, are equally limited although evidence suggests that individual and business applications are the largest growth area. More research into stakeholders' perception requirements as well as an expansion of application areas, including government, health care, education, finance, the online community and mobile applications, are needed to bridge the gap between theory and practice.

### **Empirical research**

The current research in IdMS is descriptive, and dominated by intuition-based reasoning and conceptual analysis rather than empirical investigation. Our findings show that there is a lack of empirical research on all TFI layers. Research efforts should focus on high-quality research using empirical data to develop theories. While there are many conceptual studies that represent the face value of IdMS, this implies a change in the research methods and readdresses the balance of IdMS research. Therefore, an increase in empirically-based research, such as interviews, experiments, surveys, action research and simulations, should be pursued.

### **Research into use and behaviour**

Our analysis found that the informal layer in the TFI model which encompasses the use and perceptions of IdMS is an underexplored area. Studies that focus on the context, use and perception of IdMS, from the different perspectives identified in this study, have attracted little attention. To fill this gap, more research on IdMS and behavioural consequences of IdMS use is necessary in order to examine the behaviour and beliefs as well as identifying antecedents of the adoption and usage of IdMS. Thus, we suggest that additional research into IdMS should include the interaction between users and the system. The emerging technology of biometric identification its adoption, use and consequences must also be explored.

### **Theory development**

The examination of current research in IdMS found significant gaps in conceptual models and the theories that establish them. Few theories have been applied to IdMS research. Vital issues for the IdMS topic, such as usability, trust, risk, privacy concerns and task-fit, require conceptualization and theorization in the context of identity and IdMS. In the IS field, for example, there are a number of key theories, such as the technology acceptance model (TAM) and task technology fit (TTF), that have been identified as foundations of IS research. Researchers are called upon to apply previous theories to IdMS and develop a theory through which to gain a better understanding of IdMS.

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